INSTRUCTION MANUAL

CPEC200 Closed-Path Eddy-Covariance System

Revision: 7/15

Copyright © 2013-2015
Campbell Scientific, Inc.

Limited Warranty

"Products manufactured by CSI are warranted by CSI to be free from defects in materials and workmanship under normal use and service for twelve months from the date of shipment unless otherwise specified in the corresponding product manual. (Product manuals are available for review online at *www.campbellsci.com*.) Products not manufactured by CSI, but that are resold by CSI, are warranted only to the limits extended by the original manufacturer. Batteries, fine-wire thermocouples, desiccant, and other consumables have no warranty. CSI's obligation under this warranty is limited to repairing or replacing (at CSI's option) defective Products, which shall be the sole and exclusive remedy under this warranty. The Customer assumes all costs of removing, reinstalling, and shipping defective Products to CSI. CSI will return such Products by surface carrier prepaid within the continental United States of America. To all other locations, CSI will return such Products best way CIP (port of entry) per Incoterms ® 2010. This warranty shall not apply to any Products which have been subjected to modification, misuse, neglect, improper service, accidents of nature, or shipping damage. This warranty is in lieu of all other warranties, expressed or implied. The warranty for installation services performed by CSI such as programming to customer specifications, electrical connections to Products manufactured by CSI, and Product specific training, is part of CSI's product warranty. **CSI EXPRESSLY DISCLAIMS AND EXCLUDES ANY IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE**. **CSI hereby disclaims, to the fullest extent allowed by applicable law, any and all warranties and conditions with respect to the Products, whether express, implied or statutory, other than those expressly provided herein.**"

Assistance

Products may not be returned without prior authorization. The following contact information is for US and international customers residing in countries served by Campbell Scientific, Inc. directly. Affiliate companies handle repairs for customers within their territories. Please visit *www.campbellsci.com* to determine which Campbell Scientific company serves your country.

To obtain a Returned Materials Authorization (RMA), contact CAMPBELL SCIENTIFIC, INC., phone (435) 227-9000. After an application engineer determines the nature of the problem, an RMA number will be issued. Please write this number clearly on the outside of the shipping container. Campbell Scientific's shipping address is:

CAMPBELL SCIENTIFIC, INC.
RMA#_____
815 West 1800 North
Logan, Utah 84321-1784

For all returns, the customer must fill out a "Statement of Product Cleanliness and Decontamination" form and comply with the requirements specified in it. The form is available from our web site at *www.campbellsci.com/repair*. A completed form must be either emailed to *repair@campbellsci.com* or faxed to (435) 227-9106. Campbell Scientific is unable to process any returns until we receive this form. If the form is not received within three days of product receipt or is incomplete, the product will be returned to the customer at the customer's expense. Campbell Scientific reserves the right to refuse service on products that were exposed to contaminants that may cause health or safety concerns for our employees.

Precautions

DANGER — MANY HAZARDS ARE ASSOCIATED WITH INSTALLING, USING, MAINTAINING, AND WORKING ON OR AROUND **TRIPODS, TOWERS, AND ANY ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC**. FAILURE TO PROPERLY AND COMPLETELY ASSEMBLE, INSTALL, OPERATE, USE, AND MAINTAIN TRIPODS, TOWERS, AND ATTACHMENTS, AND FAILURE TO HEED WARNINGS, INCREASES THE RISK OF DEATH, ACCIDENT, SERIOUS INJURY, PROPERTY DAMAGE, AND PRODUCT FAILURE. TAKE ALL REASONABLE PRECAUTIONS TO AVOID THESE HAZARDS. CHECK WITH YOUR ORGANIZATION'S SAFETY COORDINATOR (OR POLICY) FOR PROCEDURES AND REQUIRED PROTECTIVE EQUIPMENT PRIOR TO PERFORMING ANY WORK.

Use tripods, towers, and attachments to tripods and towers only for purposes for which they are designed. Do not exceed design limits. Be familiar and comply with all instructions provided in product manuals. Manuals are available at www.campbellsci.com or by telephoning (435) 227-9000 (USA). You are responsible for conformance with governing codes and regulations, including safety regulations, and the integrity and location of structures or land to which towers, tripods, and any attachments are attached. Installation sites should be evaluated and approved by a qualified engineer. If questions or concerns arise regarding installation, use, or maintenance of tripods, towers, attachments, or electrical connections, consult with a licensed and qualified engineer or electrician.

General

- Prior to performing site or installation work, obtain required approvals and permits. Comply with all governing structure-height regulations, such as those of the FAA in the USA.
- Use only qualified personnel for installation, use, and maintenance of tripods and towers, and any attachments to tripods and towers. The use of licensed and qualified contractors is highly recommended.
- Read all applicable instructions carefully and understand procedures thoroughly before beginning work.
- Wear a **hardhat** and **eye protection**, and take **other appropriate safety precautions** while working on or around tripods and towers.
- **Do not climb** tripods or towers at any time, and prohibit climbing by other persons. Take reasonable precautions to secure tripod and tower sites from trespassers.
- Use only manufacturer recommended parts, materials, and tools.

Utility and Electrical

- **You can be killed** or sustain serious bodily injury if the tripod, tower, or attachments you are installing, constructing, using, or maintaining, or a tool, stake, or anchor, come in **contact with overhead or underground utility lines**.
- Maintain a distance of at least one-and-one-half times structure height, 20 feet, or the distance required by applicable law, **whichever is greater**, between overhead utility lines and the structure (tripod, tower, attachments, or tools).
- Prior to performing site or installation work, inform all utility companies and have all underground utilities marked.
- Comply with all electrical codes. Electrical equipment and related grounding devices should be installed by a licensed and qualified electrician.

Elevated Work and Weather

- Exercise extreme caution when performing elevated work.
- Use appropriate equipment and safety practices.
- During installation and maintenance, keep tower and tripod sites clear of un-trained or non-essential personnel. Take precautions to prevent elevated tools and objects from dropping.
- Do not perform any work in inclement weather, including wind, rain, snow, lightning, etc.

Maintenance

- Periodically (at least yearly) check for wear and damage, including corrosion, stress cracks, frayed cables, loose cable clamps, cable tightness, etc. and take necessary corrective actions.
- Periodically (at least yearly) check electrical ground connections.

WHILE EVERY ATTEMPT IS MADE TO EMBODY THE HIGHEST DEGREE OF SAFETY IN ALL CAMPBELL SCIENTIFIC PRODUCTS, THE CUSTOMER ASSUMES ALL RISK FROM ANY INJURY RESULTING FROM IMPROPER INSTALLATION, USE, OR MAINTENANCE OF TRIPODS, TOWERS, OR ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC.

Table of Contents

PDF viewers: These page numbers refer to the printed version of this document. Use the PDF reader bookmarks tab for links to specific sections.

1. Introduction 1

2. Cautionary Statements 1

3. Initial Inspection 2

4. Overview 2

4.1 System Components 2
4.1.1 Standard Components 2
4.1.1.1 EC155 Gas Analyzer 2
4.1.1.2 EC100 Electronics 3
4.1.1.3 CPEC200 Enclosure 3
4.1.1.4 CPEC200 Pump Module 4
4.1.2 Optional Components 4
4.1.2.1 CR3000 Datalogger 4
4.1.2.2 NL115 or CFM100 Storage Module 5
4.1.2.3 CPEC200 Valve Module 6
4.1.2.4 CSAT3A Sonic Anemometer Head 6
4.1.2.5 Barometer 7
4.1.2.6 Carrying Cases 7
4.1.2.7 Enclosure Mounting Options 7
4.1.3 Common Accessories 8
4.1.4 Support Software 10
4.1.5 Replacement Parts 11
4.2 Theory of Operation 13
4.2.1 EC155 Gas Analyzer 13
4.2.2 CSAT3A Sonic Anemometer Head 13
4.2.3 Valve Module 14
4.2.4 Pump Module 15
4.3 Specifications 16

5. Installation 17

5.1 Mounting 17
5.1.1 Support Structure 17
5.1.2 Mount Enclosures 18
5.1.3 Install EC Sensors 19
5.2 Plumbing 20
5.2.1 Pump Module 21
5.2.2 Zero/Span 21
5.3 Wiring 23
5.3.1 Ground Connections 23
5.3.2 EC Sensor Cables 23
5.3.3 Pump Module Cable 26
5.3.4 Apply Power 26
5.4 Configure the Program 27
5.4.1 System Configuration Variables 28

5.4.2 Compile Switches 31
5.5 Verify Proper Operation 32

6. Zero and Span 32

6.1 Introduction 32
6.2 Automatic Zero and Span 33
6.3 Manual Zero and Span 34
6.3.1 Manually starting the zero/span sequence 35
6.3.1.1 Temperature Control 35
6.3.1.2 Starting the sequence 35
6.3.1.3 Stopping the sequence 36
6.3.2 Full Manual Control of Zero and Span 36
6.3.2.1 Getting Ready 36
6.3.2.2 Checking and Setting the Zero 37
6.3.2.3 Checking and Setting the CO_2 Span 37
6.3.2.4 Checking and Setting the H_2O Span 38
6.3.2.5 Returning to Normal EC Mode 38

7. Maintenance and Troubleshooting 39

7.1 Enclosure Desiccant 39
7.2 EC155 Intake Filter 39
7.3 EC155 Windows 40
7.4 EC155 Chemical Bottles 40
7.5 Pump Module Filter 40

8. Repair 40

Appendices

A. CPEC200 Diagnostics A-1

A.1 Overview A-1
A.2 Status Text Variables A-1
A.3 Status Boolean Variables A-6
A.4 CPEC200 Diagnostic Words A-8

B. Public Variables B-1

C. Output Variables C-1

D. Control Bits D-1

E. Using Swagelok® Fittings E-1

E.1 Assembly E-1
E.2 Common Replacement Parts E-2

F. Installing the AC/DC Power Adapter Kit F-1

G. CPEC200 Scrub Module Installation, Operation and Maintenance..... G-1

G.1 Theory of Operation..... G-1
G.2 Scrub Module Specifications..... G-2
G.3 Installation..... G-2
G.4 Maintenance..... G-3

H. CPEC200 Pump Replacement..... H-1

H.1 Introduction..... H-1
H.2 Removal..... H-1
H.3 Installation..... H-4

Figures

4-1. EC155 closed-path CO2/H2O gas analyzer....2
4-2. EC100 electronics module....3
4-3. CPEC200 system enclosure....3
4-4. CPEC200 pump module....4
4-5. CR3000 datalogger....5
4-6. NL115 (left) and CFM100 (right)....5
4-7. CFMC2G 2GB CompactFlash® memory card....5
4-8. CPEC200 valve module....6
4-9. CSAT3A sonic anemometer head....7
4-10. CPEC200 scrub module....9
4-11. 17752 USB memory card reader/writer....10
4-12. Intake filter of EC155....11
4-13. Single desiccant pack....11
4-14. Humidity indicator card....12
4-15. Diaphragm pump used in CPEC200....12
4-16. EC155 gas analyzer....13
4-17. CSAT3A sonic anemometer head....14
5-1. CPEC200 enclosure, pump module, and EC100 mounted to legs of CM110-series tripod....18
5-2. CM210 mounting bracket on a tripod mast....19
5-3. Mounting of EC155 and CSAT3A....20
5-4. Plumbing connections....20
5-5. Connecting pump tube from EC155 analyzer to pump module....21
5-6. Enclosure and tripod grounded to a copper-clad grounding rod....23
5-7. EC155 electrical connections (mounting hardware not shown)....24
5-8. Wiring of power and communications....25
5-9. Wiring to EC100 electronics....25
5-10. Wiring to CPEC200 enclosure....26
E-1. Swagelok® insert....E-3
E-2. Front and back Swagelok® ferrules....E-3
E-3. Swagelok® plug....E-4
E-4. Swagelok® cap....E-4
F-1. Peripheral mounting kit installed in CPEC200 enclosure....F-1
F-2. Power supply in mounting bracket....F-2
F-3. Secured power supply in mounting bracket....F-2
F-4. Connections for the power supply in CPEC200 enclosure....F-3
F-5. Powered supply in CPEC200 enclosure....F-3
G-1. CPEC200 scrub module....G-1
G-2. Scrub module interior....G-3

G-3. Interior of CPEC200 scrub module with tubing and cover removed G-4
G-4. Empty bottle showing the top (on the right with spring) and bottom (left) caps G-5
H-1. Four screws holding filter assembly inside CPEC200 pump module enclosure H-1
H-2. Upright filter unit in enclosure H-2
H-3. Location of #4 screws of pump assembly H-2
H-4. Exposed CPEC200 pump assembly H-3
H-5. Location of pump connector in CPEC200 pump electronics H-3
H-6. Self-tapping screws attaching pump to metal box H-4
H-7. Location of cuts to remove pump assembly from tubing H-4
H-8. Inlet and outlet tubing reconnected to pump H-5
H-9. Pump side with inlet and outlet tubing connected H-5
H-10. Proper positioning of CPEC200 in shell cover H-6

Tables

5-1. SDM Wiring 24
6-1. Automatic Zero/Span Sequence 34
A-1. Summary CPEC200 diagnostic flags encoded in diag_cpec A-9
B-1. CPEC200 public variables B-1
C-1. Values stored in table ts_data C-1
C-2. Values stored in table flux C-3
C-3. Values stored in table zero_ span C-6
C-4. Values stored in table message_log C-9
C-5. Values stored in table config_history C-10
D-1. CPEC200 temperature control bits encoded in ControlBits D-1
E-1. Available plastic tubing sizes, construction, and usage guidelines ..E-2
E-2. Dimensions and part numbers for Swagelok® inserts E-3
E-3. Dimensions and part numbers for Swagelok® ferrules E-3
E-4. Dimensions and part numbers for Swagelok® plugs E-4
E-5. Dimensions and part numbers for Swagelok® caps E-4

CPEC200 Closed-Path Eddy-Covariance System

1. Introduction

The CPEC200 is a closed-path, eddy-covariance (EC) flux system used for long-term monitoring of atmosphere–biosphere exchanges of carbon dioxide, water vapor, heat, and momentum. This complete, turn-key system includes a closed-path gas analyzer (EC155), a sonic anemometer head (CSAT3A), datalogger (CR3000), sample pump, and optional valve module for automated zero and span.

Before using the CPEC200, please study:

- Section 2, *Cautionary Statements*
- Section 3, *Initial Inspection*
- Section 5, *Installation*

Operational instructions critical to the preservation of the system are found throughout this manual. Before using the CPEC200, please study the entire manual. Further information pertaining to the CPEC200 can be found in the Campbell Scientific publications *EC155 CO_2 and H_2O Closed-Path Gas Analyzer Manual*, available at www.campbellsci.com.

Other manuals that may be helpful include:

- *CR3000 Micrologger Operator's Manual*
- *CFM100 CompactFlash® Module Instruction Manual*
- *NL115 Ethernet and CompactFlash® Module Instruction Manual*
- *Application Note 3SM-F, PC/CF Card Information*
- *LoggerNet Instruction Manual*
- *ENC10/12, ENC12/14, ENC14/16, ENC16/18 Instruction Manual*
- *CM106 Tripod Instruction Manual*
- *Tripod Installation Manual Models CM110, CM115, CM120*
- *CSAT3 Three Dimensional Sonic Anemometer Manual*

NOTE This user manual applies specifically to version 2.0 of the CPEC200 CRBasic program.

2. Cautionary Statements

- WARNING:
  - Do not connect or disconnect the EC155 gas analyzer head or the CSAT3A sonic anemometer head from the EC100 electronics while the EC100 is powered. Doing so can result in unpredictable performance of the system or damage to the instrument head.
  - Grounding electrical components in the measurement system is critical. Proper earth (chassis) grounding will ensure maximum electrostatic discharge (ESD) protection and higher measurement accuracy.
  - Use care when connecting and disconnecting tube fittings to avoid introducing dust or other contaminants.

- Do not overtighten the tube fittings. Consult Appendix E, *Using Swagelok® Fittings*, for information on proper connection.
- The CPEC200 power source should be designed thoughtfully to ensure uninterrupted power. If needed, contact a Campbell Scientific application engineer for assistance.
- Retain all spare caps and plugs as these are required when shipping or storing the CPEC200 system.

3. Initial Inspection

Upon receipt of the CPEC200, inspect the packaging and contents for damage. File damage claims with the shipping company.

Model numbers are found on each product. On cables, the model number is usually found at the connection end of the cable. Check this information against the enclosed shipping documents to verify the expected products and the correct lengths of cable are included.

4. Overview

The CPEC200 is a closed-path EC flux system used for long-term monitoring of atmosphere–biosphere exchanges of carbon dioxide, water vapor, heat, and momentum.

4.1 System Components

The CPEC200 consists of several components, some of which are optional. Some additional accessories are required to complete a fully functioning CPEC200 system and are described and illustrated in the sections that follow.

4.1.1 Standard Components

Standard with the CPEC200 are the CPEC200 system enclosure, EC155 gas analyzer, EC100 electronics, and CPEC200 pump module.

4.1.1.1 EC155 Gas Analyzer

The EC155 is a closed-path, infrared CO_2/H_2O gas analyzer. It shares integrated electronics (EC100 electronics) with the CSAT3A sonic anemometer head. For detailed information and specifications, see the EC155 manual at *www.campbellsci.com*. The EC155, as shown in FIGURE 4-1, is an included part of the CPEC200 system.

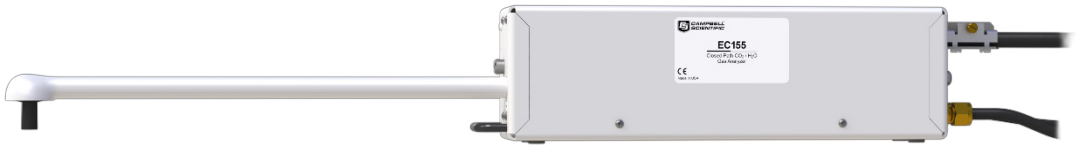

FIGURE 4-1. EC155 closed-path CO2/H2O gas analyzer

4.1.1.2 EC100 Electronics

The EC100 electronics module (FIGURE 4-2) controls the EC155 and CSAT3A. It is housed in its own enclosure and must be mounted within 3 m of the sensors.

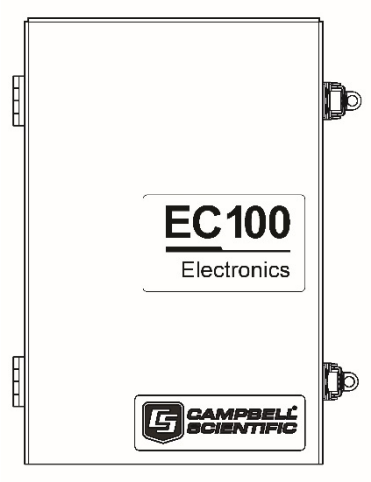

FIGURE 4-2. EC100 electronics module

4.1.1.3 CPEC200 Enclosure

The CPEC200 enclosure (FIGURE 4-3) houses the CR3000 datalogger, control electronics, the optional valve module, and communications and power terminals. Several options for mounting to a tower, tripod, or large diameter pole can be specified when ordering the system.

FIGURE 4-3. CPEC200 system enclosure

4.1.1.4 CPEC200 Pump Module

The pump module (FIGURE 4-4) uses a small, low-power diaphragm pump to draw air through the EC155 sample cell. The pumping speed is automatically controlled to maintain the volumetric flow at the setpoint (3 to 7 LPM). The pump module is temperature controlled to keep the pump in its operating temperature range of 0 to 55 °C. The pump module includes a large-capacity filter to protect the pump from contamination and dampen pressure fluctuations in the sample cell that are caused by the pump.

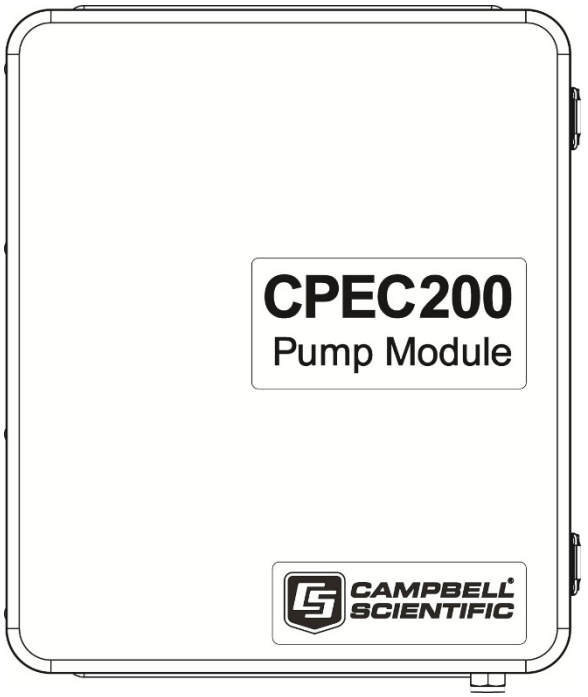

FIGURE 4-4. CPEC200 pump module

4.1.2 Optional Components

4.1.2.1 CR3000 Datalogger

The CR3000 datalogger (FIGURE 4-5) is housed in the CPEC200 enclosure. The CR3000 executes and stores measurements from all sensors. It calculates online flux measurements, and stores both raw and processed data. Although the CR3000 is a required component, the CPEC200 can be purchased without the CR3000. However, the user must supply a CR3000 with the low-profile base option.

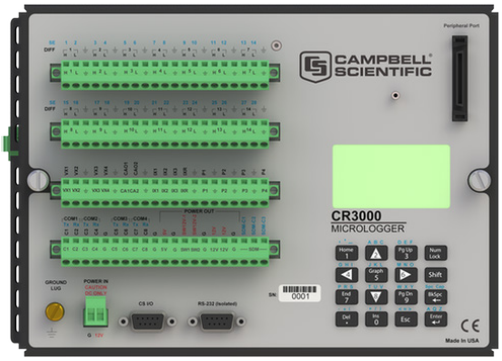

FIGURE 4-5. CR3000 datalogger

4.1.2.2 NL115 or CFM100 Storage Module

The datalogger saves data onto a CompactFlash® (CF) memory card (FIGURE 4-7) via an optional NL115 or CFM100 card module (FIGURE 4-6). Either module will provide data storage. The NL115 has the added capabilities that are available with the Ethernet interface.

FIGURE 4-6. NL115 (left) and CFM100 (right)

The CPEC200 can be ordered with either of the storage modules factory installed. If the CPEC200 is ordered without a storage module, the user must provide one. The CF card (FIGURE 4-7) can be ordered separately from www.campbellsci.com. For details, see the *CFM100 CompactFlash® Module Instruction Manual* or the *NL115 Ethernet and CompactFlash® Module Instruction Manual*, and the *Application Note 3SM-F, PC/CF Card Information*. All manuals are available at www.campbellsci.com.

FIGURE 4-7. CFMC2G 2GB CompactFlash® memory card

4.1.2.3 CPEC200 Valve Module

The optional CPEC200 valve module (FIGURE 4-8) is housed in the CPEC200 enclosure and is used to automate zero and CO_2 span checks, and automatically perform a field zero and field CO_2 span on a user-defined interval. Field H_2O span requires a dewpoint generator and cannot be automated because the dewpoint generator is a laboratory instrument. Therefore, H_2O spans must be performed manually.

The CPEC200 valve module is available in two versions, one with three valves (pn 27559) and another with six valves (pn 26578). The valve module is normally ordered as a factory-installed option of the CPEC200, but the module can also be ordered separately and installed by the user.

FIGURE 4-8. CPEC200 valve module

4.1.2.4 CSAT3A Sonic Anemometer Head

The CSAT3A (FIGURE 4-9) is Campbell Scientific's 3D sonic anemometer sensor head. It shares integrated electronics (EC100 electronics) with the EC155 gas analyzer. For detailed information and specifications, see the CSAT3 manual.

NOTE Campbell Scientific's standalone sonic anemometer, the CSAT3, has its own electronics box, whereas the CSAT3A shares the EC100 electronics with the EC155 gas analyzer. The measurement specifications for the CSAT3 and CSAT3A are the same.

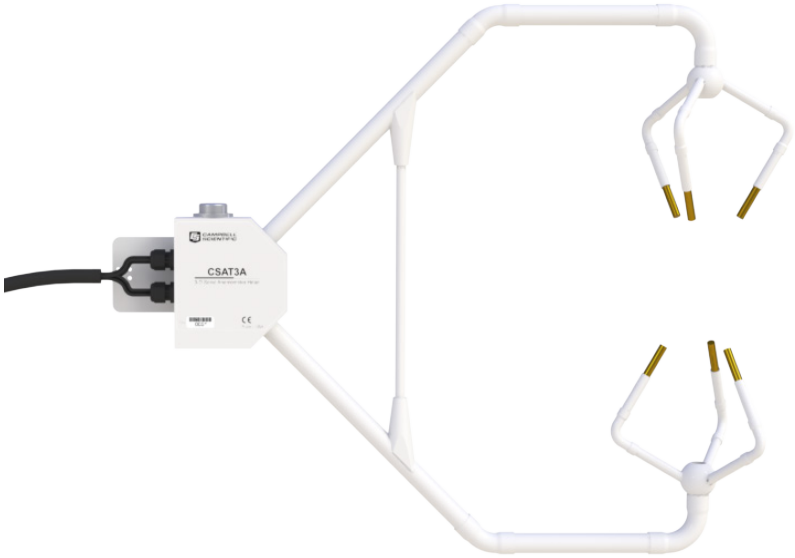

FIGURE 4-9. CSAT3A sonic anemometer head

4.1.2.5 Barometer

The EC100 is always configured with an EC100 basic barometer. However, an EC100 enhanced barometer is available as an option. The decision to upgrade to the enhanced barometer is largely dependent on the specific site and environmental constraints for a given site. In general, the enhanced barometer provides overall greater accuracy, but may not be a necessary upgrade for many applications.

Unlike open-path systems, the accuracy of the CPEC200 system is influenced by the sample cell pressure. The EC155 sample cell pressure is measured by a differential pressure sensor that measures the sample cell pressure relative to barometric pressure (as measured by the EC100 barometer). The accuracy of the sample cell pressure measurement is the sum of the accuracy of the barometer in the EC100 and the differential pressure sensor in the EC155.

The measurement rate is likewise affected by both the sample cell pressure and the specific barometric pressure of the barometer – either basic or enhanced. The differential pressure sensor is always measured at 10 Hz, while the basic barometer is measured at 10 Hz and the enhanced barometer is measured at 1 Hz.

For greater detail, see Section 4.3, *Specifications*, of this manual or consult a Campbell Scientific application engineer for specific sites and applications.

4.1.2.6 Carrying Cases

The EC155 and the CSAT3A may be ordered with optional carrying cases. If the carrying cases are not ordered, the sensors are shipped in cardboard boxes.

4.1.2.7 Enclosure Mounting Options

The CPEC200 system enclosure and the CPEC200 pump module can be configured with one of several mounting options. The CPEC system enclosure is similar to the Campbell Scientific ENC16/18 enclosure, and the CPEC200

pump module is similar to the ENC10/12 enclosure. The same mounting options are available and outlined below:

- Triangular tower (UT10, UT20, or UT30)
- Tripod mast 3.8 cm (1.5 in) to 4.8cm (1.9 in) diameter
- Tripod leg (CM106 or CM106K tripod only)
- Large pole 10.2 cm (4.0 in) to 25.4 cm (10.0 in) diameter
- No mounting bracket

Consult the *ENC10/12, ENC12/14, ENC14/16, ENC16/18 Instruction Manual*, available at *www.campbellsci.com*, for details on mounting bracket options.

4.1.3 Common Accessories

There are several items that may be required to complete the installation, but are not included in the CPEC200. Some of the more common accessories are:

System Power Cable: Two power cables are required for the CPEC200; one for the main CPEC200 system and one for the EC100 electronics.

The preferred power cable, CABLEPCBL-L, consists of a twisted red/black pair of wire gauge (AWG) 16 within a rugged Santoprene™ jacket. It is cut to the specified length and the end is finished for easy installation.

NOTE The "-L" designation after certain parts designates a cable or tube length in feet. The length is specified by the user at the time of order.

SDM Cable: An SDM communication cable is required to connect the EC100 to the CPEC200 system enclosure. The preferred SDM cable is CABLE4CBL-L. This cable consists of four conductors with a shield and drain wire, and a rugged Santoprene™ jacket. It is cut to the specified length and the end is finished for easy installation.

Pump Tube: A tube must be used to connect the EC155 to the pump module. If the EC155 is within 50 ft of the pump module, 3/8-in OD tubing, such as pn 26506, is recommended. For longer distances (up to 500 ft), a larger 1/2-in OD tube (pn 25539) is recommended to minimize pressure drop in the tube. Pre-swaged pump tube assemblies, such as pn 26504-L, 3/8-in OD, or pn 26503-L, 1/2-in OD, are available for this purpose.

NOTE The fittings on the EC155 and the pump module are sized for 3/8-in OD tubing. A reducer is required at each end for the larger tubing size. These reducers are supplied as part of the pre-swaged tube assembly.

Zero/span tubes: Tubes must be used to connect the EC155 and the zero and CO_2 span cylinders to the valve module. Bulk tubing may be cut to length and installed onsite using pn 15702 or its equivalent. This tubing has a 1/4-in OD to fit the Swagelok® fittings on the EC155 and the valve module. The tubing has an aluminum core to minimize diffusion through the tubing wall and a UV-resistant, black, high-density polyethylene jacket. Maximum tubing length available is a 500-ft roll.

Minimize the length of these tubes to reduce the amount of equilibration time required after the zero or CO_2 span cylinder is selected. One long tube is required to connect the valve module to the EC155, and two short tubes are required to connect the zero and CO_2 span cylinders to the valve module. Pre-swaged tube assemblies (pn 21823-L) are available for this purpose.

CPEC200 Scrub Module: The CPEC200 scrub module (pn 27423) provides a source of zero air and is used for zeroing the EC155. It consists of a pump and a three-stage molecular sieve and connects to the CPEC200 system enclosure. The scrub module (shown in FIGURE 4-10) eliminates the need for a cylinder of zero air. A cylinder of known CO_2 is still required. The module reduces the need for one of the two cylinders for zero/span and is useful in locations where transporting and replacing cylinders is inconvenient. Additional information regarding installation and maintenance of the CPEC200 scrub module can be found in Appendix G, *CPEC200 Scrub Module Installation, Operation and Maintenance*.

FIGURE 4-10. CPEC200 scrub module

AC/DC Power Adapter Kit: An AC/DC adapter kit (pn 28549) can be configured within the CPEC200 system enclosure with a peripheral mounting kit (pn 16987). This configuration allows the CPEC200 to be powered from AC mains power. See Appendix F, *Installing the AC/DC Power Adapter Kit*, for more information.

CF Card: The CPEC200 stores data on a CompactFlash® memory card. There are two types of CF cards available today: industrial grade and standard or commercial grade. Industrial grade PC/CF cards are certified to a higher standard in that they are designed to operate over a wider temperature range, offer better vibration and shock resistance, and have faster read/write times than their commercial counterparts. Campbell Scientific recommends the use of industrial-grade cards, such as the CFMC2G or CFMC16G (FIGURE 4-7)

available from Campbell Scientific. For more details about this card, see *Application Note 3SM-F, PC/CF Card Information*, available from www.campbellsci.com.

USB Memory Card Reader/Writer: The USB memory card reader/writer (pn 17752) is shown in FIGURE 4-11. It is a single-slot, high-speed reader/writer that allows a computer to read a memory card. When used with Campbell Scientific equipment, the 17752 typically reads data stored on CompactFlash® cards, but it can read many different types of memory cards.

FIGURE 4-11. 17752 USB memory card reader/writer

4.1.4 Support Software

There are several software products available for interfacing a PC to the CPEC200's datalogger.

***PC200W*:** *PC200W* is a free, starter software package that provides basic tools such as clock set, program download, monitor data, retrieve data, etc. *PC200W* supports direct connections between PC and datalogger but has no telecommunications or scheduled data-collection support.

***PC400*:** *PC400* is a mid-level software package that supports a variety of telecommunication options, manual data collection, data display, and includes a full-featured CRBasic program editor. *PC400* does not support combined communication options (for example, phone-to-RF), PakBus® routing, or scheduled data collection.

***LoggerNet*:** *LoggerNet* is a full-featured software package that supports programming, communication, and data collection and display. *LoggerNet* consists of a server application and several client applications integrated into a single product. This package is recommended for applications that require telecommunications support, scheduled data retrieval, or for large datalogger networks.

LoggerLink Mobile Apps: The LoggerLink Mobile Apps allows an iOS or Android device to communicate with an IP-enabled datalogger such as the CR3000. The apps support field maintenance tasks such as viewing and collecting data, setting the clock, and downloading programs.

4.1.5 Replacement Parts

Intake Filter: The EC155 intake filter (FIGURE 4-12) will become clogged over time and must be replaced. The default replacement part is pn 26072. It is a 2.5-cm (1.0-in) diameter, sintered stainless steel disk filter with a 20 µm pore size encased in a molded Santoprene™ shell. An alternative 40 µm filter (pn 28698) is also available. Use a 40 µm filter if the default 20 µm filter clogs long before the EC155 optical windows become dirty.

FIGURE 4-12. Intake filter of EC155

Sonic Wicks: A sonic wicks spares kit (pn 28902) is used to replace the wicks on the CSAT3A. The kit includes three top wicks, three bottom wicks, an installation tool, and adhesive.

Silica Desiccant Bags: Silica desiccant bags (FIGURE 4-13) are used to desiccate the CPEC200 system enclosure and should be periodically replaced. A single four-unit silica desiccant bag is pn 4905. These can be purchased in quantities of 20 as pn 6714.

DO NOT EAT
UNITED DESICCANTS-GATES
101 CHRISTINE, BELEN, NEW MEXICO 87002
DESI PAK
SPECIFICATION MIL-D-3464 TYPE I &II
REACTIVATION TIME IN-BAG 16 HOURS AT 250 F°
DESICCANT ACTIVATED BAGGED FOR
CONTENTS 4 UNITS
PACKAGE USE AND STATIC DEHUMIDIFICATION
DO NOT EAT
UNITED DESICCANTS-GATES
101 CHRISTINE, BELEN, NEW MEXICO 87002
DESI PAK
SPECIFICATION MIL-D-3464 TYPE I &II
REACTIVATION TIME IN-BAG 16 HOURS AT 250 F°
DESICCANT ACTIVATED BAGGED FOR
CONTENTS 4 UNITS
PACKAGE USE AND STATIC DEHUMIDIFICATION

FIGURE 4-13. Single desiccant pack

Humidity Indicator Card: The replacement humidity indicator card (FIGURE 4-14) provides a visual reference of humidity level inside the enclosure. A single replacement card is pn 28878.

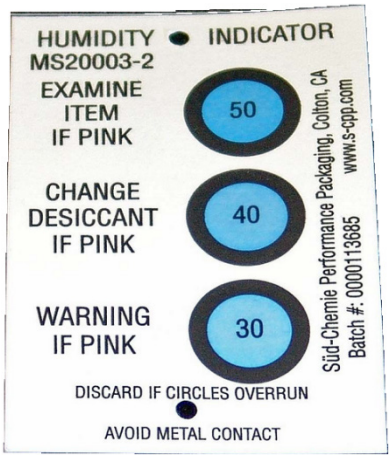

FIGURE 4-14. Humidity indicator card

EC155 Replacement Chemical Bottles: The EC155 has two small bottles filled with chemicals to remove CO_2 and water vapor from the inside of the sensor head. If replacement bottles are needed, two bottles are included with pn 26511.

Diaphragm Pump: The pump module for the CPEC200 includes a small double-head diaphragm pump with a brushless DC motor. The pump includes a speed-control input and a tachometer to measure actual pumping speed. It is mounted in an insulated, temperature-controlled box inside the CPEC200 system enclosure. If the pump fails, the replacement pump (FIGURE 4-15) is available as pn 26402. The part includes the connector for easy installation. See Appendix H, *CPEC200 Pump Replacement*, for instructions on replacing the pump.

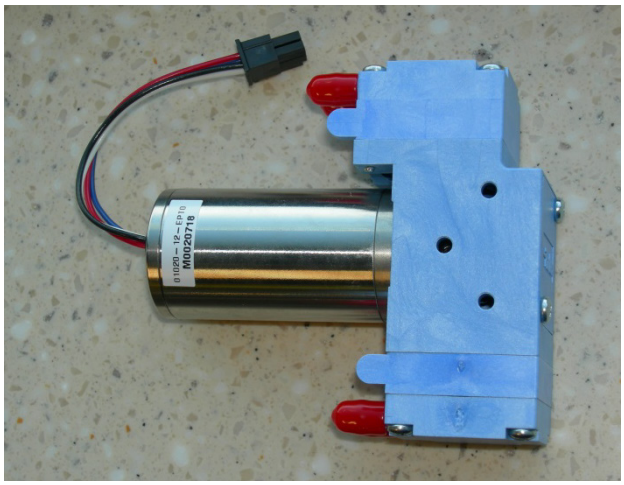

FIGURE 4-15. Diaphragm pump used in CPEC200

4.2 Theory of Operation

The CPEC200 is used for long-term monitoring of atmosphere–biosphere exchanges of carbon dioxide, water vapor, heat, and momentum. This complete, turn-key system includes a closed-path gas analyzer (EC155), a sonic anemometer head (CSAT3A), datalogger (CR3000), sample pump, and an optional valve module for automated zero and span.

4.2.1 EC155 Gas Analyzer

The EC155 (FIGURE 4-16) is Campbell Scientific's closed-path, mid-infrared absorption gas analyzer that measures molar mixing ratios of carbon dioxide and water vapor. More information about the operation of the EC155 can be found in the manual, *EC155 CO_2 and H_2O Closed-path Gas Analyzer* at www.campbellsci.com.

FIGURE 4-16. EC155 gas analyzer

4.2.2 CSAT3A Sonic Anemometer Head

The CSAT3A, as shown in FIGURE 4-17, is an ultrasonic anemometer sensor head for measuring wind speed in three dimensions. It shares integrated electronics, the EC100 electronics, with the EC155 gas analyzer. It is similar to the sensor head for the CSAT3 sonic anemometer, with the primary difference being that the CSAT3 can be used as a standalone anemometer because it includes independent electronics. The CSAT3A uses three nonorthogonal pairs of transducers to sense the wind velocity vector. Each pair of transducers transmits and receives ultrasonic pulses to determine the time of flight, which is directly related to the speed of sound and the wind speed along the line between the pair of transducers. The CSAT3A transforms the results into orthogonal wind components u_x, u_y, and u_z, referenced to the anemometer head.

The CSAT3A also determines the speed of sound for each transducer pair. These measurements are averaged and converted to sonic virtual temperature (T_s) based on the relationship between speed of sound and air temperature. For more detailed information and specifications, see the CSAT3 manual.

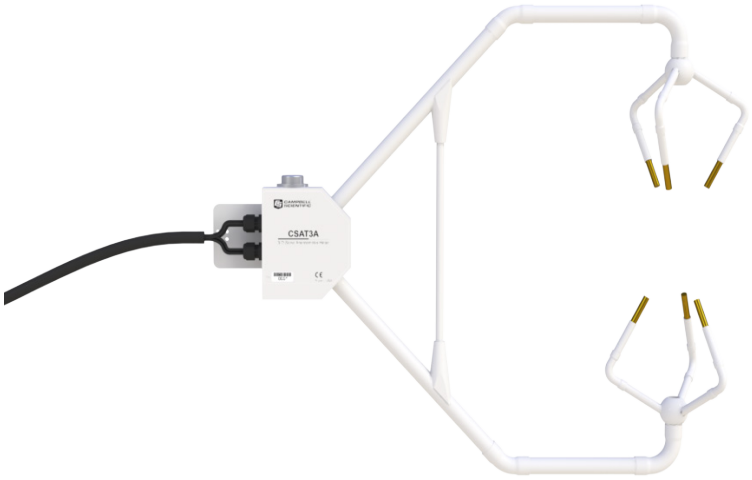

FIGURE 4-17. CSAT3A sonic anemometer head

4.2.3 Valve Module

The optional valve module, shown in FIGURE 4-8, is housed in the CPEC200 enclosure and is used to automate zero and CO_2 span checks, and automatically perform a zero and CO_2 span on a user-defined interval. As described in Section 4.1.2.3, *CPEC200 Valve Module*, H_2O span requires a dewpoint generator and cannot be automated.

The CPEC200 valve module is available in two versions, one with three valves (pn 27559) and another with six valves (pn 26578). The valve module is normally ordered as a factory-installed option, but can also be ordered separately and installed by the user.

For the three-valve version, the inputs are:

- Zero
- CO_2 Span 1
- H_2O Span

For the six-valve version, the inputs are:

- Zero
- CO_2 Span 1
- CO_2 Span 2
- CO_2 Span 3
- CO_2 Span 4
- H_2O Span

The CPEC200's zero and CO_2 span inlets are not bypass equipped, meaning that they flow only when selected. This allows the zero and CO_2 span tanks to be continuously connected for automatic, unattended operation.

The **H_2O Span** input is bypassed (vented to the atmosphere through the **H_2O Span Bypass** outlet) when it is not selected, so it permits flow all the time. This allows a dewpoint generator to be connected directly to the **H_2O Span** inlet. The dewpoint generator's internal pump can push flow into the valve module even when the **H_2O Span** valve is not selected, minimizing errors

caused by pressurization inside the dewpoint generator. When the **H_2O Span** valve is selected, the dewpoint generator pushes moist air through the valve module to the EC155.

The CPEC200 pushes the zero/span flow backward through the EC155 sample cell and exhausts it through the intake tube to the atmosphere. Flow through the intake tube causes the sample-cell pressure to rise slightly above ambient pressure. The CPEC200 infers the flow rate from this pressure rise. The EC155 has a differential pressure sensor to measure this pressure rise directly, but its accuracy is affected by a small offset drift. The accuracy of this differential pressure measurement can be improved by stopping all flow through the EC155, allowing the pressure in the sample cell to equilibrate with ambient pressure, and measuring the differential pressure offset. This offset is then subtracted from subsequent measurements used to control the flow.

Because the pressure sensor offset can change over time, this offset is measured at the beginning of every zero/span cycle. This step requires at least 10 seconds to complete; 5 seconds for the pressure to equilibrate, and 5 seconds to average and store the differential pressure measurement.

Either of the CPEC200 valve modules have a proportional control valve to actively control the flow of zero and span gas to the EC155. The CPEC200 program adjusts public variable **valveControl** between 0 (closed) and 1 (fully open) as needed for the measured flow **valve_flow** to reach the desired flow, as indicated by **CAL_FLOW_SETPT**. The default value for **CAL_FLOW_SETPT** is 1.0 LPM. This flow is adequate for lower measurement heights (allowing a shorter tube between the valve module and the EC155), but setting a higher flow rate may be required with long zero/span delivery tubes used on tall towers. The proportional valve is opened fully during an H_2O span operation to prevent pressurizing the dewpoint generator.

The CPEC200 valve module includes a heater and a fan to keep the valves within their operating range of 0 to 60 °C. The valve heater turns on/off at 2 °C. The valve fan turns on at 50 °C and stays on until the valve temperature drops to 48 °C. To conserve power, temperature control is active just prior to and during the time when valves are in use. If the valves cannot be maintained within the temperature range, the valves are disabled. The valve module temperature control can be manually activated so that manual zero/span can be performed by the station operator on site or remotely. If starting from the minimum ambient temperature (–30 °C), the valves may take as much as 15 min to warm up to the operating range of 0 to 60 °C.

4.2.4 Pump Module

The CPEC200 pump module pulls air through the system and exhausts it through the **Exhaust** fitting on the bottom of the enclosure. It uses a small double-head diaphragm pump with a brushless DC motor. This pump includes a speed control input and a tachometer to measure the actual pumping speed. It is mounted in an insulated, temperature-controlled box located inside the weather-tight fiberglass enclosure. The pump module includes a large filter cartridge to dampen the pressure fluctuations from the pump and to protect the pump from particulates or debris.

If the pump fails, the replacement pump is available as pn 26402 (see Section 4.1.5, *Replacement Parts*). See Appendix H, *CPEC200 Pump Replacement*,

for instructions on replacing the pump. The filter cartridge in the pump module is unlikely to clog over the lifetime of the CPEC200 system.

The following sections describe operating parameters of the pump.

Pump Speed: The pump tachometer is measured, converted to volumetric flow rate, and reported in public variable **pump_flow**. The CPEC200 sets the value of public variable **pump_control** to a value between 0 (off) and 1 (full speed) to adjust the pump's speed as needed to match **pump_flow** to the setpoint flow **PUMP_SETPT**. **PUMP_SETPT** is a system configuration variable (see Section 5.4.1, *System Configuration Variables*).

Pump Inlet Pressure: The measured inlet pressure of the pump is reported in public variable **pump_press**. This pressure will normally be slightly lower (~1 kPa) than the EC155 sample cell pressure due to the pressure drop in the pump tube.

Pump Temperature: The temperature of the pump module is reported in public variable **pump_tmpr**. The operating range of the pump is 0 to 55 °C. If the pump temperature is outside this range, the CPEC200 will disable the pump. The pump module has a heater (drawing 8 W while operational) that turns on if the pump temperature falls below 2 °C. If the CPEC200 is started at cold temperature, it may take up to 50 minutes to warm the pump module (from –30 to 0 °C). When it reaches 2 °C the heater will cycle on/off as needed to maintain this temperature.

The pump module has a fan (drawing 0.7 W while operational) that turns on if the pump temperature rises above 45 °C. The fan will stay on until the pump temperature falls below 40 °C.

The outlet of the pump connects the **Exhaust** fitting on the bottom of the pump module enclosure. This fitting has a screen to prevent insects or debris from entering when the pump is off.

4.3 Specifications

System

Operating temperature:	–30 to 50 °C
Input voltage:	10.5 to 16.0 Vdc
Power:	12 W (typical), 35 W (max, at cold startup)

System enclosure

Dimensions:	52.1 x 44.5 x 29.7 cm (20.5 x 17.5 x 11.7 in)
Weight basic system:	11.6 kg (25.5 lb)
CR3000:	1.6 kg (3.7 lb)
CFM100/NL115:	0.2 kg (0.4 lb)
Three-valve module:	1.5 kg (3.3 lb)
Six-valve module:	1.9 kg (4.2 lb)

Pump module

Cable length:	3.0 m (10 ft)
Inlet connection:	3/8-in Swagelok®
Pressure sensor range:	15 to 115 kPa
Pumping speed:	3 to 9 LPM (automatically controlled at the set-point, typically 7 LPM)
Dimensions:	35.6 x 29.2 x 13.5 cm (14.0 x 11.5 x 5.3 in)
Weight w/ out mounting:	5.4 kg (11.8 lb)

Valve module

Flow rate:	1 to 5 LPM (automatically controlled at the set-point, typically 1 LPM)
Inlets	
Three-valve module:	Zero, CO_2 span, and H_2O span
Six-valve module:	Zero, CO_2 spans 1 through 4, and H_2O span
Outlets:	Analyzer and H_2O bypass
Connections:	1/4-in Swagelok®
Dimensions:	14.0 x 12.7 x 14.0 cm (5.5 x 5.0 x 5.5 in.)
Weight	
Three-valve module:	1.5 kg (3.3 lb)
Six-valve module:	1.9 kg (4.2 lb)

EC155 and CSAT3A Specifications: see the user manual: *EC155 CO_2 and H_2O Closed-path Gas Analyzer Manual* and *CSAT3 Three Dimensional Sonic Anemometer Manual*

5. Installation

The following tools are required to install the CPEC200 system in the field. Additional tools may be required for a user-supplied tripod or tower.

- 9/16-in, open-end wrench
- 1/2-in, open-end wrench
- 11/16-in, open-end wrench
- Adjustable wrench
- Small, flat-tip screwdriver (included with EC100 and CPEC200)
- Large, flat-tip screwdriver (included with EC100)
- Sledgehammer (to drive grounding rod into the ground)
- 3/16-in hex-key wrench (included with CM250 leveling mount)

5.1 Mounting

5.1.1 Support Structure

The CPEC200 system has four major components that must be mounted to a user-provided support structure. The support structure itself is not included in the CPEC200 so that it can be tailored to specific needs, but several options are available. Contact a Campbell Scientific application engineer for more information on site-specific mounting options.

EC sensors (EC155 and CSAT3A): Mounted on a horizontal round pipe of 3.33 cm (1.31 in) outer diameter, such as the CM20X crossarm.

EC100 electronics: Mounted within 3.0 m (10 ft) of the EC sensors. The EC100 mounting bracket will accommodate a pipe at any orientation, with outer diameter from 2.5 cm to 4.8 cm (1.0 in to 1.9 in).

CPEC200 enclosure: Mounted where it can be accessed easily to retrieve data from the CF cards on the datalogger. The CPEC200 enclosure is similar to the ENC16/18, with the same mounting options (tower, tripod, leg, or pole).

CPEC200 pump module: Mounted within 3.0 m (10 ft) of the CPEC200 enclosure. The pump module enclosure is similar to the ENC10/12, with the same mounting options (tower, tripod, leg, or pole).

Consult the *ENC10/12, ENC12/14, ENC14/16, ENC16/18 Instruction Manual*, available at www.campbellsci.com, for details on mounting bracket options.

The following sections describe a typical application using a CM110 tripod and CM202 crossarm. The CPEC200 enclosure and the CPEC200 pump module are shown with the leg-mount options. The CM110 tripod and the leg mounting options, shown in FIGURE 5-1, are ideal for a low EC measurement height to minimize wind disturbance.

5.1.2 Mount Enclosures

Mount the EC100 electronics within 3.0 m (10 ft) of the EC sensors (this measurement corresponds to the length of the cables on the EC155 and the CSAT3A).

NOTE The EC100 should be mounted vertically to prevent water ingress from precipitation.

The mounting bracket will accommodate a horizontal, vertical, or angled pipe from 2.5 cm to 4.8 cm (1.0 in to 1.9 in) diameter. See the EC155 user manual for details on configuring the EC100 mounting bracket. The EC100 electronics are shown mounted on one leg of a CM110 tripod in FIGURE 5-1.

Mount the CPEC200 enclosure and the CPEC200 pump module within 3.0 m (10 ft) distance. The enclosure and pump module are shown mounted back-to-back on the leg of a CM110 tripod in FIGURE 5-1, but they may also be mounted on a vertical pipe, triangular tower, or large-diameter pole, depending on the site requirements and the mounting options ordered.

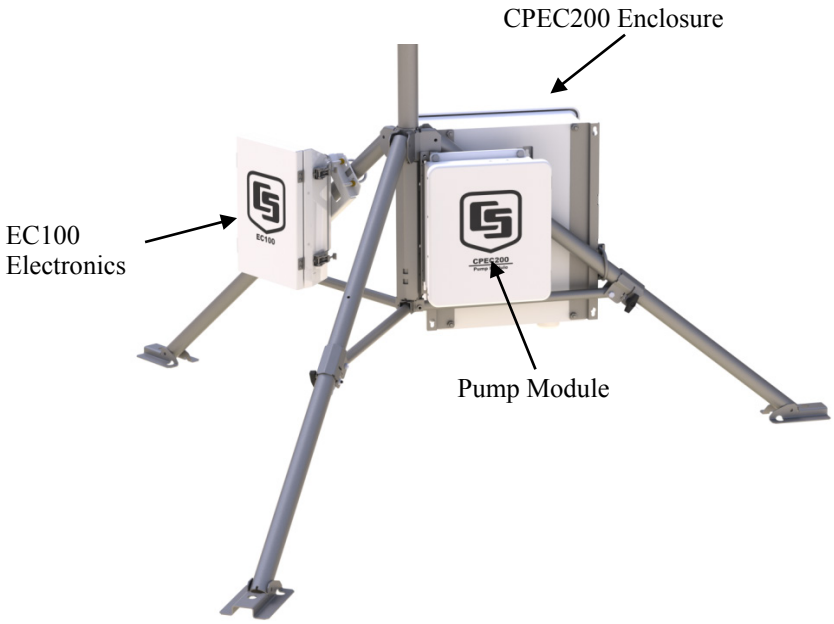

FIGURE 5-1. CPEC200 enclosure, pump module, and EC100 mounted to legs of CM110-series tripod

For the EC100 and the system enclosure, open the sealed bag containing the desiccant packs and humidity card. Place two of the desiccant packs and the humidity indicator card in the mesh pocket in the enclosure door. Reseal the remaining two desiccant packs in the bag to use later.

5.1.3 Install EC Sensors

Install a horizontal mounting crossarm at the height desired for the EC measurement. This crossarm must be within ±15 degrees of horizontal to level the sonic anemometer. Point the crossarm into the predominant wind direction to minimize wind disturbance caused by wind flowing past the mounting structure and EC sensors. The outer diameter of the crossarm should be 3.3 cm (1.3 in). The CM202 crossarm is shown in FIGURE 5-2.

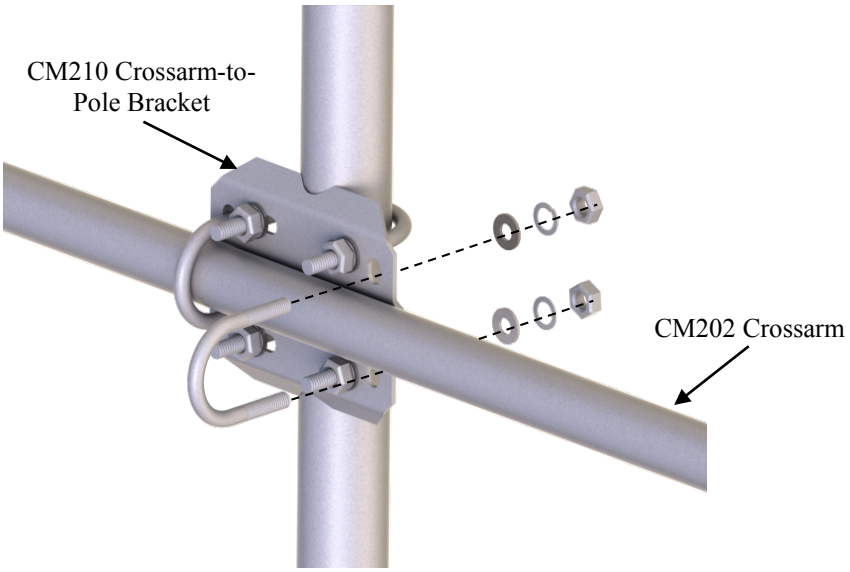

FIGURE 5-2. CM210 mounting bracket on a tripod mast

The EC155 gas analyzer and CSAT3A sonic anemometer head are mounted on the end of the crossarm using the CM250 leveling mount and the CPEC200 mounting platform, as shown in FIGURE 5-3. Adjust the tilt of the mounting platform to level the CSAT3A. For more details see instructions in the *EC155 CO_2 and H_2O Closed-path Gas Analyzer* manual.

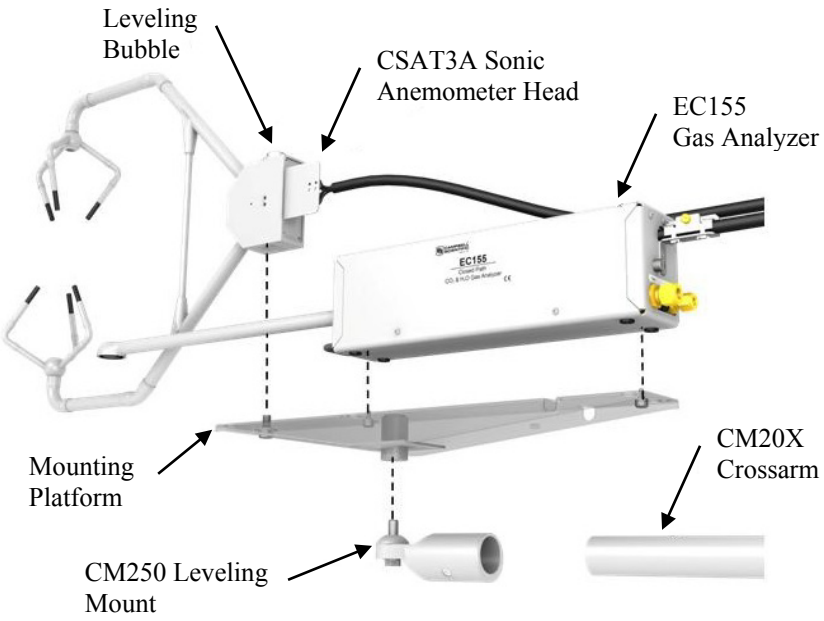

FIGURE 5-3. Mounting of EC155 and CSAT3A

5.2 Plumbing

FIGURE 5-4 shows the basic plumbing configuration of a CPEC200 including the cylinders required for zero and span operations.

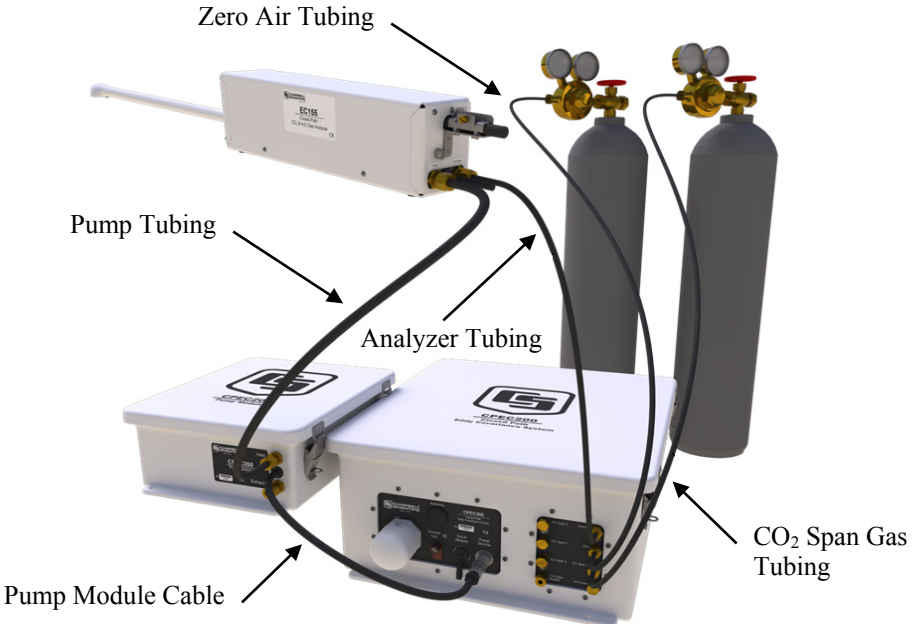

FIGURE 5-4. Plumbing connections

5.2.1 Pump Module

Connect the EC155 to the pump module, see FIGURE 5-5. If the EC155 is within 15 m (50 ft) of the pump module, 3/8-in OD tubing, such as pn 26506, is recommended. For longer distances of up to 150 m (500 ft), a 1/2-in OD tube (pn 25539) is recommended to minimize pressure drop in the tube.

NOTE The fittings on the EC155 and the pump module are sized for 3/8-in OD tubing. A reducer is required at each end for the larger tubing size. Campbell Scientific supplies pre-swaged pump tube assemblies pn 26503-L (1/2-in OD), with reducers at each end for this purpose.

Connect one end of the pump tube to the fitting labeled **Pump** on the back of the EC155 analyzer. Connect the other end to the fitting labeled **Inlet** on the CPEC200 pump module as shown in FIGURE 5-5.

FIGURE 5-5. Connecting pump tube from EC155 analyzer to pump module

5.2.2 Zero/Span

The CPEC200 can perform automated zero (CO_2 and H_2O) and CO_2 span of the EC155. In most cases the user must supply cylinders of zero air and CO_2 span gas with appropriate regulators. If the user has chosen the optional CPEC200 scrub module, then no cylinder of zero air is required. The rest of this section assumes the use of cylinders of compressed gas, but see Appendix

G, *CPEC Scrub Module Installation, Operation and Maintenance*, for details on the scrub module. Install cylinders in close proximity to the CPEC200 system enclosure. Each cylinder must have a pressure regulator to control the outlet pressure at 10 psig and must have a 1/4-in Swagelok® fitting on the outlet. Connect regulators to the valve module inlets using 1/4-in OD tubing, such as pn 15702, or pre-swaged tube assemblies (pn 21823-L). Minimize the length of these tubes to reduce the equilibration time after the zero or CO_2 span cylinder is selected. Refer to Appendix E, *Using Swagelok® Fittings,* for information on installing and replacing Swagelok® fittings.

NOTE Flow meters and needle valves are not needed because the CPEC200 valve module has a proportional-control valve to actively control the flow of zero and span gas to the EC155.

NOTE Make sure there are no leaks in the regulators or the connections to the valve module. For automatic operation, the tank shutoff valves are left continuously open. A plumbing leak could cause the contents of the tank to be lost.

NOTE When inlets are not in use, replace the Swagelok® plugs to keep the system clean.

Connect the valve module's **Analyzer** outlet to the **Zero/Span** fitting on back of the EC155 analyzer. Similar tubing (pn 15702) or pre-swaged tube assembly (pn 21823-L) is recommended for this connection. The length of this tube should also be minimized to reduce equilibration time.

If the CPEC200 has been configured with the six-valve module, additional CO_2 span cylinders may be connected to the additional CO_2 Span inlets on the valve module.

Open the shutoff valves on the cylinders and set the pressure regulators for 10 ± 5 psig delivery pressure.

NOTE If you inadvertently adjust the pressure too high, you may need to slightly loosen the tube fitting to bleed off the excess pressure. Retighten the fitting when the proper setting is reached.

The **H2O Span** inlet is bypass equipped, allowing continuous flow. This inlet can be connected directly to the output of a dewpoint generator. The bypass on this inlet will avoid pressurizing the dewpoint generator.

NOTE Some systems, such as the AP200 CO_2/H_2O Atmospheric Profile system, require a tee in the connection from the dewpoint generator to bleed off excess flow and avoid pressurizing the dewpoint generator. Do not use a tee to connect a dewpoint generator to the CPEC200.

5.3 Wiring

5.3.1 Ground Connections

The CPEC200 system enclosure and the EC100 electronics must be earth grounded as illustrated in FIGURE 5-6. Ground the tripod and enclosures by attaching heavy gage grounding wire (12 AWG minimum) to the grounding lug found on the bottom of each enclosure. The other end of the wire should be connected to earth ground through a grounding rod. For more details on grounding, see the grounding section of the *CR3000 Micrologger Operator's Manual*.

FIGURE 5-6. Enclosure and tripod grounded to a copper-clad grounding rod

5.3.2 EC Sensor Cables

Ensure the EC100 is not powered. Connect the EC155 gas analyzer head, EC155 sample cell, and CSAT3A sonic anemometer head to the EC100 electronics. FIGURE 5-7 shows the electrical connections described in this section. For more details see the *EC155 CO_2 and H_2O Closed-Path Gas Analyzer Manual*.

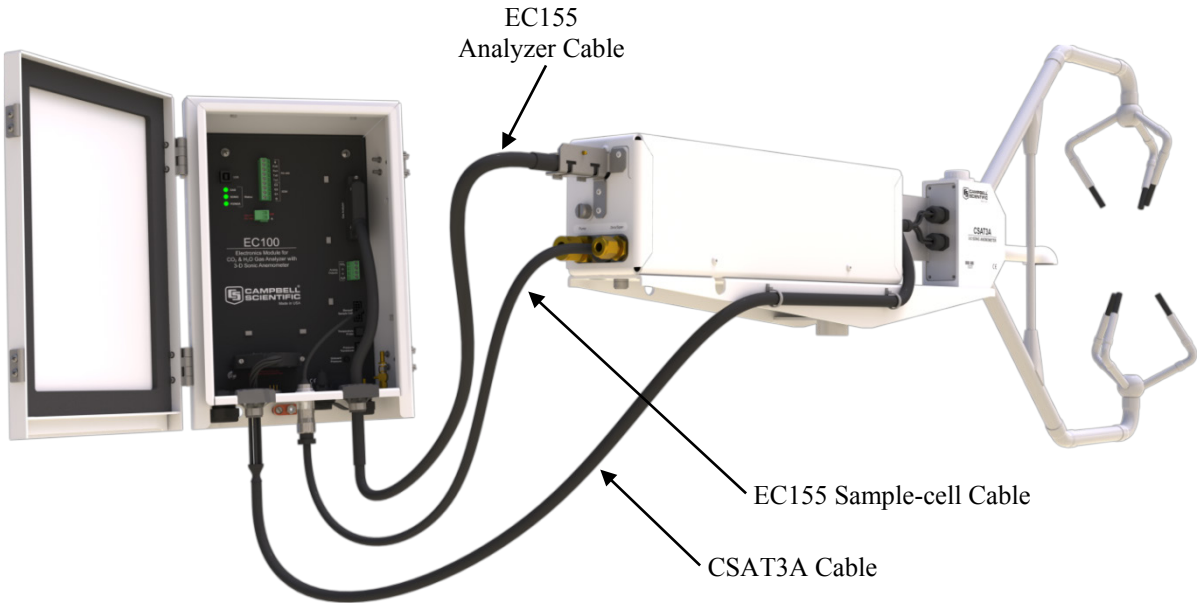

FIGURE 5-7. EC155 electrical connections (mounting hardware not shown)

Wire the SDM communications cable (CABLE4CBL-L) between the EC100 and the CPEC200 enclosure as shown in FIGURE 5-8, FIGURE 5-9, and FIGURE 5-10. TABLE 5-1 shows the color scheme of the SDM wires.

TABLE 5-1. SDM Wiring

Description	Wire Color	EC100	CPEC200
SDM Data	Green	SDM-C1	SDM-C1
SDM Clock	White	SDM-C2	SDM-C2
SDM Enable	Red	SDM-C3	SDM-C3
Digital Ground	Black	Ground	Ground
Shield	Clear	Ground	Ground

NOTE To bring cables into the CPEC200 enclosure, remove the cap from the cable feedthrough by loosening the thumbscrew and twisting the cap while pulling it off.

NOTE To connect a wire to the DIN rail terminal blocks of the CPEC200 enclosure, insert a small screwdriver into the square hole to open the spring-loaded contacts. Insert the wire into the corresponding round hole and then remove the screwdriver. Gently tug the wire to confirm it is secure.

Ensure the CPEC200 enclosure is not powered, and wire the power cable (CABLEPCBL-L) from the EC100 electronics to the CPEC200 enclosure as shown in FIGURE 5-8, FIGURE 5-9, and FIGURE 5-10.

Secure the SDM and power cables in the EC100 with a cable tie.

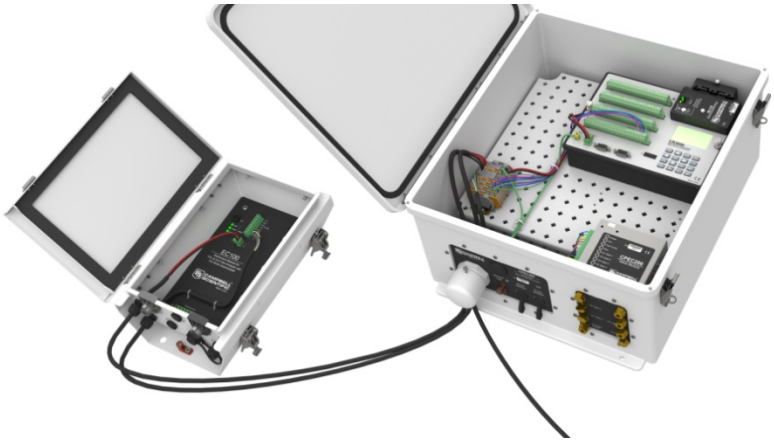

FIGURE 5-8. Wiring of power and communications

FIGURE 5-9. Wiring to EC100 electronics

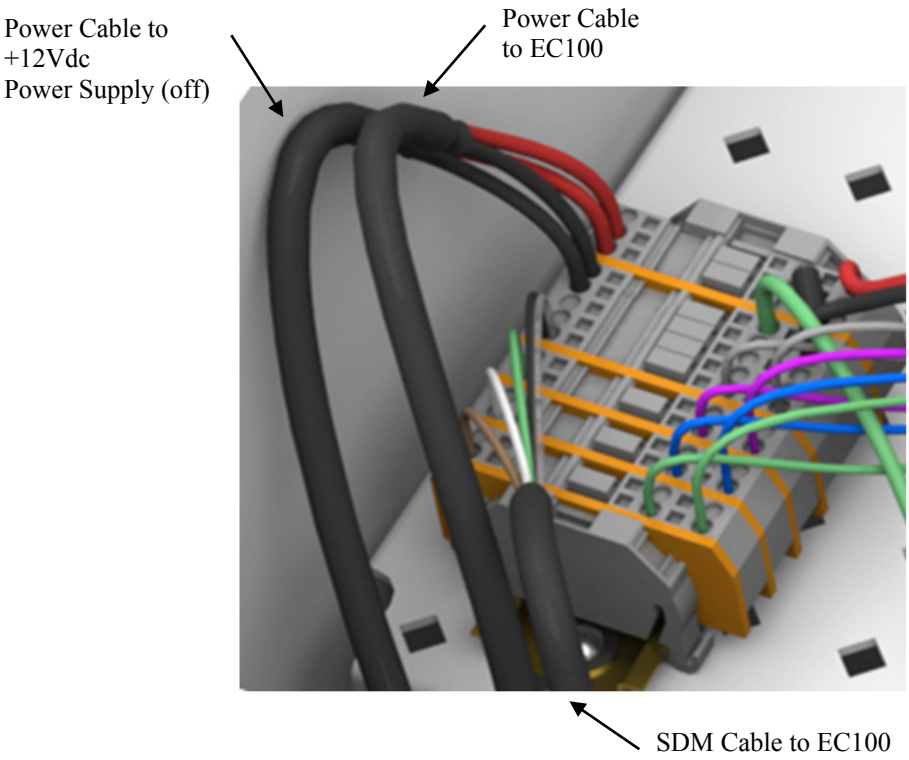

FIGURE 5-10. Wiring to CPEC200 enclosure

5.3.3 Pump Module Cable

Ensure the CPEC200 system is not powered, and connect the pump module cable to the bottom of the CPEC200 system enclosure.

5.3.4 Apply Power

The CPEC200 requires a 10.5 to 16.0 Vdc power source. Its average power consumption is 12 W typical but will be slightly higher at cold temperatures, especially at startup in cold weather. In typical remote applications the power will be supplied from a user-provided 12 Vdc battery system charged with solar panels. If AC mains power is available it may be convenient to use the AC/DC power adapter (see Appendix F, *Installing the AC/DC Power Adapter Kit*) for details.

NOTE Before applying power, verify all of the tubes and cables have been connected according to the instructions above.

CAUTION To reduce the risk of shorting the power supply, especially when using batteries, connect the power cable to the CPEC200 first and then connect the other end to the power source. Carefully design any DC power source to ensure uninterrupted power. If needed, contact a Campbell Scientific application engineer for assistance.

Connect a power cable (CABLEPCBL-L) from the CPEC200 power terminals, as shown in FIGURE 5-10, to a user-supplied, 12 Vdc power supply.

Relieve strain on the cables in the CPEC200, by using a cable tie to secure the cables to the cable-tie loop on the plate next to the CPEC200 DIN rail.

Replace the cap on the CPEC200 enclosure feedthrough. Gently bend the cables back as you slide the cap on and rotate the cap to minimize the space around the cables. Tighten the thumbscrew to further relieve strain on the cable. This will also minimize air infiltration and extend the life of the enclosure desiccant packs.

NOTE In very humid conditions it may be helpful to seal the cable feedthrough with plumber's putty.

NOTE The CPEC200 stores energy in a capacitor to provide backup power in the event power is interrupted. The capacitor will power the datalogger for a few seconds allowing it to finish writing data to the CF card and close the file to prevent loss of data or damage to the CF card. Do not attach additional sensors or other devices that are powered from the datalogger without consulting a Campbell Scientific application engineer.

5.4 Configure the Program

A CR3000 datalogger program **Cpec200_vx_x.cr3** is included with the CPEC200 system. If the CPEC200 was ordered with the CR3000 factory installed, the CPEC200 is shipped with the program installed. A copy of the program is found on the *CPEC200 Support CD* (pn 26857) or can be downloaded from *www.campbellsci.com*.

The CPEC200 program uses both constants and variables to customize the behavior of the system for a particular installation. Constants are used for parameters that must be determined when the program is compiled and variables are used otherwise.

Constants are most easily modified using the CRBasic Editor, which is part of the *PC400* and *LoggerNet* datalogger support software packages. They may also be edited with a simple text editor and uploaded to the datalogger using *PC200W*, which may be downloaded from *www.campbellsci.com*. The CPEC200 uses some constants as "compile switches" to define the state of the system during compilation.

Variables may be edited while the program is running using either a keyboard display or a PC connected through *PC200W*, *PC400*, or *LoggerNet*. Variables that define the operational configuration of the system are defined as system configuration variables. Any changes to these variables are automatically saved in nonvolatile memory.

NOTE Modifications to the CPEC200 program (for example, to measure additional sensors) are not recommended without first consulting a Campbell Scientific application engineer.

5.4.1 System Configuration Variables

Several special variables are used to configure the CPEC200. These variables are included at the end of TABLE B-1 in Appendix B, *Public Variables*, and are distinguished by all capital letters. They may be edited directly in the **public** table or with the keypad display on the datalogger.

These variables are stored in the **sys_conf_var.dat** file so their values will be saved and recalled if the program is recompiled. They are intended to be set when a new system is installed but may be edited at any time. When a system configuration variable is changed, the CPEC200 will write a message to the **message_log** table and save the new values in **sys_conf_var.dat**. It will also add a record to the **config_history** table. This section gives a brief description of each of these variables and refers the reader to the appropriate section of the user manual if a lengthy discussion is required.

BATT_LOWLIMIT:
If the supply voltage **BattVolt** falls below this value, the CPEC200 will set **BattVolt_OK** = **False** and shut down as much of the system as possible until the voltage recovers. **BATT_LOWLIMIT** must be 10.0 V to 15.0 V. The default value for **BATT_LOWLIMT** is 10.0 V, which corresponds to 10.3 V at the input terminal. This power-down feature is to protect the battery from deep discharge cycles. The user should set **BATT_LOWLIMIT** as appropriate to protect the battery. If AC main power and an AC/DC adapter are used, the limit may be left at 10.0 V.

BATT_DEADBAND:
This variable, along with **BATT_LOWLIMIT**, determines when the CPEC200 will restart after an automatic power shutdown. The CPEC200 will not restart until the supply voltage **BattVolt** reaches at least **BATT_LOWLIMIT + BATT_DEADBAND**. The purpose of the deadband function (the gap between the shutdown voltage and the turn-on voltage) is to protect the CPEC200 from repeated power cycles when the battery voltage is very near the limit. **BATT_DEADBAND** must be between 0 and 10.0 V. The default is 1.0 V.

SONIC_AZIMUTH:
The variable **SONIC_AZIMUTH** specifies the angle in degrees between true north and the direction that the sonic anemometer is pointing. For example, if the sonic anemometer is pointing due east, set **SONIC_AZIMUTH** to 90°. If the sonic anemometer is pointing southwest, enter 225°, and so on. **SONIC_AZIMUTH** is used to calculate **wnd_dir_compass**.

BANDWIDTH:
The CPEC200 program configures the EC155 bandwidth according to system configuration variable **BANDWIDTH**. This variable may be set to any of the valid settings: 5, 10, 12 (12.5 Hz), 20, or 25. The CPEC200 program will save the updated setting in the configuration file, configure the EC100 electronics and update the lag time.

NOTE The IRGA data will be invalid for up to one second after changing the bandwidth as the EC100's digital filter is reinitialized for the new bandwidth setting.

The default setting is 20 (20 Hz bandwidth), which preserves all of the high-frequency fluctuations in the CO_2 and H_2O measurements. If the raw time series are processed to give spectra, the user generally should set **BANDWIDTH** to 5 (5 Hz). This will filter the IRGA data to avoid aliased response.

For more information, see the *EC155 CO_2 and H_2O Closed-Path Gas Analyzer Manual* available at www.campbellsci.com.

AMB_PRESS_NOMINAL:
This is a backup for when the differential pressure sensor is not used. If **USE_DIFF_PRESS = False**, then the value entered here is used for the ambient pressure in flux calculations. Otherwise the EC100 barometer (basic or enhanced) is used, and this variable is ignored. See Section 4.1.2.5, *Barometer*, for more discussion on the interaction between the EC100 barometer and the differential pressure sensor.

NOTE

The EC100 always includes the EC100 basic barometer, but it may be ordered with the optional EC100 enhanced barometer. The EC100 is configured at the factory to use the enhanced barometer, if ordered. Normally, the user will not have to change this setting. If there is a need to check or change this setting, see the EC155 user manual.

PUMP_SETPT:
Variable **PUMP_SETPT** determines the volumetric flow rate at which the pump will draw the air sample through the EC155 sample cell. **PUMP_SETPT** must be 3 to 9. The default setting is 7.0 LPM. In tall tower applications where decreased frequency response is acceptable, lowering the flow rate may be desirable as it will prolong the life of the intake filter. This may be particularly applicable if the site is dusty or if accessing instruments on the tower is difficult. Decreasing the flow by a factor of two will generally lead to a four-fold increase in filter lifetime.

CAL_INTERVAL:
This variable determines how often (given in minutes) the calibration (zero/span) sequence will be run. It is ignored if **CHECK_ZERO** = **False**. The minimum time is the output interval (30 min). The maximum time is 1,440 min, or once per day. The default is 1,440.

CAL_TIMEOFFSET:
This variable determines when the calibration (zero/span) sequence is started within the **CAL_INTERVAL** time. If **CAL_TIMEOFFSET = 0**, the calibration sequence will start at the start of the **CAL_INTERVAL**. Setting this variable to a non-zero value will delay the start of the zero/span sequence by the set number of minutes. **CAL_TIMEOFFSET** may be set to any value from zero to **CAL_INTERVAL**. The default is 59, which will start the zero/span sequence 59 minutes past midnight. This avoids starting the zero/span sequence at midnight, when the datalogger has the extra processing tasks associated with closing and opening files for the **ts_data** table. It starts the sequence one minute before the end of an averaging period. The sequence is generally longer than one minute, so the EC samples that are lost to the zero/span sequence are split between two consecutive flux output intervals.

ZERO_TIME:
Determines the time (given in seconds) for the zero gas to flow while checking the zero. **ZERO_TIME** must be 20 to 300. The default is 60, which should be adequate for low measurement heights. For taller towers, increase the time as needed to allow the EC155 response to equilibrate after the zero air begins to flow.

SPAN_TIME:
Determines the time (given in seconds) for the CO_2 span gas to flow. Time for zero and CO_2 span may need to be different to allow the H_2O to fully equilibrate during the zero. If the scrub module is used for the zero air, the flow rate will be different for zero and CO_2 span. This is another reason to set the zero and span times differently. **SPAN_TIME** must be 20 to 300. The default is 30, which should be adequate for low measurement heights. For taller towers, increase the time as needed to allow the EC155 response to equilibrate after the CO_2 span gas begins to flow.

CAL_FLOW_SETPT:
Determines the rate at which the zero or CO_2 span gas will flow. The path the gas takes is from the cylinder, through the valve module to the EC155 analyzer, and out the end of the EC155 intake.

The CPEC200 valve module has a proportional control valve to actively control the flow of zero and span gas. This flow rate can be changed by changing the value of public variable **CAL_FLOW_SETPT**. The default for zero and span gas flow is 1.0 LPM, but higher zero/span flow rates may be required with the long zero/span delivery tubes required for tall tower installations. The maximum zero/span flow rate is 5.0 LPM.

If a scrub module is used to provide the zero air, this setpoint is ignored and the flow rate is determined by the pump in the scrub module. The proportional valve in the valve module will be fully open.

Similarly, during an H_2O span, this setpoint is ignored and the flow rate is determined by the pump in the dewpoint generator. The proportional valve will be fully open.

CO2_SPAN_PPM:
This is the concentration of the CO_2 span cylinder, in ppm ($\mu mol\ mol^{-1}$). If **CHECK_ZERO, CHECK_SPAN1,** and **SET_SPAN_1** all = **TRUE**, the system will automatically span the IRGA to this value during the zero/span sequence. This value is also used during a manual CO_2 span operation. **CO2_SPAN_PPM** must be between 300 and 1000.

USE_DIFF_PRESS:
This variable configures the EC100 electronics to use the differential pressure sensor in the EC155 sample cell. The default is **True**. This should be changed to **False** only if the user has connected the EC155 sample cell to some other pressure sensor. For more details, see the *EC155 CO_2 and H_2O Closed-Path Gas Analyzer Manual*, available at *www.campbellsci.com*.

The next set of system configuration variables determine which steps of the zero/span sequence are to be performed and which steps will be skipped.

CHECK_ZERO:
Check the gas analyzer zero against the zero gas. This is used as a flag to completely disable the zero/span sequence. If **CHECK_ZERO = False**, the CPEC200 will not do the automatic sequence.

SET_ZERO:
Set the gas analyzer zero (CO_2 and H_2O).

CHECK_SPAN1:
Check the gas analyzer span against CO_2 gas number 1.

SET_SPAN_1:
Set the gas analyzer span using CO_2 gas number 1.

CHECK_SPAN2:
Check the gas analyzer span against CO_2 gas number 2 (requires the 6-valve module).

CHECK_SPAN3:
Check the gas analyzer span against CO_2 gas number 3 (requires the 6-valve module).

CHECK_SPAN4:
Check the gas analyzer span against CO_2 gas number 4 (requires the 6-valve module).

5.4.2 Compile Switches

The CPEC200 program defines four constants that are used as compile switches. The function of these constants are defined below.

VALVE_MODULE:
Set **VALVE_MODULE = True** to enable the use of the optional valve module. Set it to **False** if no valve module is installed, or if the valve module is not being used. Disabling the valve module by setting it to **FALSE** will reduce clutter in the output tables and save processing time. No distinction is made between the 3-valve module or the 6-valve module. Either one is enabled by setting **VALVE_MODULE = True**.

SCRUB_MODULE:
Set **SCRUB_MODULE = True** to enable the use of the scrub module accessory. Set **SCRUB_MODULE = False** if no scrub module is installed.

NOTE

Setting **SCRUB_MODULE = True** when using a cylinder of compressed zero air instead of a scrub module may cause the contents of the zero air cylinder to be quickly exhausted.

Use of the scrub module requires the use of the valve module. If **VALVE_MODULE = False,** then **SCRUB_MODULE** will be ignored.

SaveAll_diagnostics:
If constant **SaveAll_diagnostics** = **False** (the default), the **ts_data** output table will contain only those values required for normal operation. If **SaveAll_diagnostics** = **True**, the CPEC200 will save some additional diagnostic values in output table **ts_data**.

Leaf_Wetness_Sensor:
If an optional leaf wetness sensor is installed, set **Leaf_Wetness_Sensor = True** to reduce power to the EC155 intake heater during dry weather. If **Leaf_Wetness_Sensor = False**, the EC155 intake heater will be set to full power (0.7 W) all the time.

5.5 Verify Proper Operation

Verify proper operation of the CPEC200 system by checking the following public variables.

Public variable **mode_status** describes the basic operating state of the CPEC200. Verify **mode_status** = *Normal EC mode*. See Appendix A, *CPEC200 Diagnostics*, for further information.

Public variable **cpec_status** gives an overall status for the entire system. If there are no problems detected, **cpec_status** will report *CPEC is OK*. See Appendix A, *CPEC200 Diagnostics*, for further information.

If the CPEC200 was not configured with the optional valve module, the installation is now complete. If the valve module is installed, use the zero/span capability of the CPEC200 as described in Section 6, *Zero and Span*.

6. Zero and Span

6.1 Introduction

The EC155 must be zeroed and spanned periodically to maintain its accuracy. This requires the user to supply cylinders of zero air and CO_2 span gas and appropriate regulators.

NOTE Use high-quality gases for the zero and CO_2 span. The zero gas must be free of significant water vapor and CO_2. The CO_2 span gas should have a well-known concentration of CO_2, balanced in air (not nitrogen).

There are three ways that the EC155 can be zeroed and spanned:

1. The EC155 can be zeroed and spanned independently of the CPEC200 system, per the instructions in the *EC155 CO_2 and H_2O Closed-Path Gas Analyzer Manual*. This option can zero and span both CO_2 and H_2O. This is the only choice if the CPEC200 was configured without the optional valve module.

2. The EC155 zero and CO_2 span may be performed automatically by the CPEC200 system. This requires the CPEC200 be configured with the optional valve module. This method can zero both CO_2 and H_2O but

can span only CO_2. Further details for this option are given in Section 6.2, *Automatic Zero and Span*.

3. The optional valve module allows the EC155 zero and span to be performed manually at the field site. If the CPEC200 has been configured with an internet connection, the manual zero and span may also be done remotely. Although CO_2 and H_2O zero, and CO_2 span may be performed remotely, H_2O span requires the dewpoint generator to be brought to the field site. Further details for this option are given in Section 6.3, *Manual Zero and Span*.

See Section 5.2.2, *Zero/Span*, for details on plumbing connections to zero and span the EC155 while installed in the CPEC200. The following sections give details on configuring the CPEC200 for either automatic or manual zero and span.

In addition to identifying the most appropriate use of manual versus automatic and remote versus onsite calibration, there is one additional option to consider: whether to simply *check* the zero/span, or to *set* the zero/span.

Checking the zero/span allows the user to track the performance of the EC155, apply gain and offset corrections in post processing, and decide when to actually set the zero/span. Setting the zero/span involves sending commands to the EC155 to update its internal zero/span parameters.

NOTE Campbell Scientific recommends setting the zero/span in the EC155 as this will maintain better accuracy than applying corrections in post processing. See the *EC155 CO_2 and H_2O Closed-Path Gas Analyzer Manual* for details.

The recommended approach for zero/span involves both monitoring and setting the zero/span according to the following steps:

1. Measure the H_2O span with a dewpoint generator.
2. Measure the CO_2 span.
3. Measure the CO_2 and H_2O zero.
4. Set the CO_2 and H_2O zero in the EC155.
5. Measure the CO_2 span again (after zero has been set).
6. Set the CO_2 span in the EC155.
7. Measure the H_2O span again (after zero has been set).
8. Set the H_2O span in the EC155.

NOTE Steps 1, 7, and 8 require the use of the dewpoint generator and must be omitted for remote operations, including the automated zero/span.

6.2 Automatic Zero and Span

The automatic zero/span sequence consists of eleven steps, listed in TABLE 6-1. If **CHECK_ZERO = True**, the CPEC200 will periodically cycle through the sequence as listed. If **CHECK_ZERO = False**, the CPEC200 will continue to sample atmospheric air for eddy covariance measurements (no automatic zero/span).

mode_status is the text variable that reports the status of the sequence. Pump on/off is reported in public variable **pump_ON**. Public variable **valve_number** shows which valve is active. The status of **valve_number** is displayed to the user in two manners; in the public and output tables as the actual numeric value of an integer from 0 to 6, or as text on the datalogger keypad. TABLE 6-1 gives both the datalogger keypad text and the corresponding numeric value in the public and output tables. The duration of each step is also given in TABLE 6-1. Some of the steps have a duration that cannot be changed, while others are set by the configuration variables **SPAN_TIME** and **ZERO_TIME**.

NOTE Step 2 and steps 4 through 9 are optional, as determined by the configuration variables. If a step is disabled, it is skipped.

TABLE 6-1. Automatic Zero/Span Sequence

Step	Mode Status	Pump	valve_number		Duration (sec)
			Keypad	Value	
1	Measuring Pressure	Off	None	0	10
2	Checking CO2 Span 1	Off	CO2span1	2	SPAN_TIME
3	Checking Zero	Off	ZeroAir	1	ZERO_TIME
4	Setting Zero	Off	ZeroAir	1	10
5	Rechecking CO2 Span 1	Off	CO2span1	2	SPAN_TIME
6	Setting CO2 Span 1	Off	CO2span1	2	10
7	Checking CO2 Span 2	Off	CO2span2	3	SPAN_TIME
8	Checking CO2 Span 3	Off	CO2span3	4	SPAN_TIME
9	Checking CO2 Span 4	Off	CO2span4	5	SPAN_TIME
10	Equilibrating for EC	On	None	0	10
11	Switching to EC mode	On	None	0	0.1

6.3 Manual Zero and Span

There are two ways to manually zero/span the IRGA in the CPEC200:

1. The zero/span sequence may be run at any time by initiating the sequence manually. This will often be the easiest way to do a manual zero/span, but the sequence cannot do the H_2O span. At the completion of the sequence the system will automatically return to EC mode.

2. The user may manually control each step in the zero/span process. Using full manual control allows the H_2O to be spanned. It also bypasses some of the automated checking. For example, full manual control will allow the user to do a zero or span even if there is a diagnostic flag.

The two approaches to doing a manual zero/span are described below:

6.3.1 Manually starting the zero/span sequence

6.3.1.1 Temperature Control

Both the valve and scrub modules have heaters and fans to keep them within their operating temperature range. Generally, this temperature control function is disabled to conserve power. If the CPEC200 is configured for automatic zero/span sequences, it will automatically enable temperature control of the valve and scrub modules before the zero/span sequence is scheduled to begin. This allows the valve module and scrub module to reach operating temperature range even in very cold weather.

To initiate a zero/span sequence manually, first turn on the temperature control for the valves by setting **valveTctl_ON** = **True**. The keyboard display's menu makes this easy if there is onsite access to the datalogger. Navigate the menus as follows:

Manual Zero/Span → Temperature Control

The temperature control can also be enabled by setting the public variable directly (using *LoggerNet*, for example).

Public variable **valve_status** gives information on the temperature of the valve module and scrub module, if used. If temperature control is disabled (**valveTctl_ON** = **False**), **valve_status** will report *Valves are in standby mode (temperature control is disabled)*. If temperature control is enabled (**valveTctl_ON** = **True**), **valve_status** will report *Valves are ready* if the valve module and scrub module are within their operating temperatures. Otherwise, it will report whether the valve module or scrub module temperature is either too high or too low.

6.3.1.2 Starting the sequence

When the valve module and scrub module, if used, reach their operating temperature range, and **valve_status** reports *Valves are ready*, you may start the zero/span sequence. If either module is outside of its operating range when you attempt to initiate the sequence, the sequence will not start, and an error message will be written to the **message_log** table and displayed in public variable **latest_note**.

To manually start the automatic zero/span sequence, set **STARTsequence** = **True**. This will cause the zero/span sequence to run (see Section 6.2, *Automatic Zero and Span*, for details on setting up the sequence). The keyboard display has a menu to make this easy if there is onsite access to the datalogger. Navigate the menus as follows:

Manual Zero/Span → Run Zero/Span Seq

The zero/span sequence can also be initiated by simply setting the public variable **STARTsequence** directly. At the conclusion of a manually initiated zero/span sequence, the CPEC200 will automatically resume EC mode. It will automatically disable temperature control of the valve module and scrub module.

Running the zero/span sequence manually will write results to the **Zero_Span** table, just as if the sequence was run automatically by the system. This record

of the zero/span process is another advantage of using the sequence instead of full manual control.

6.3.1.3 Stopping the sequence

Normally the zero/span sequence will run to completion, and the CPEC200 will automatically disable valve temperature control and return to EC mode. To manually stop the sequence while it is running, turn the pump on by setting **pump_ON** = **True**. This will stop the sequence, turn the valves off, disable valve temperature control, turn the pump on, and return to EC mode.

6.3.2 Full Manual Control of Zero and Span

In some cases it may be more appropriate to run the zero/span under full manual control. This allows the user to decide how much time is required for the zero or span gas to reach equilibrium, or to perform additional status checking. It also allows the H_2O to be spanned. The keyboard display has menus to facilitate manual zero/span control for users that are onsite.

Navigate:

Manual zero/span → Manual Control

6.3.2.1 Getting Ready

There are two tasks to prepare for manual zero/span control. First, enable the temperature control for the valves and the scrub module (if being used) as noted above.

Second, measure the pressure offset. The keyboard display has menus to facilitate manual zero/span control for users that are onsite. Navigate:

Manual zero/span → Manual Control → Pressure Offset

Turn the sample pump off by setting **pump_ON** = **False** to enter manual zero/span mode. Verify **mode_status** has changed from *Normal EC mode* to *Manual Zero/Span mode.*

NOTE If the CPEC200 program is not configured for valve operation, **mode_status** will report *Standby mode (Pump is Off)*. See Appendix A, *CPEC200 Diagnostics*, for further details.

Tip: Normally a manual zero/span is started when the CPEC200 is in the EC mode (pump on). In that case, turn the pump off to begin a manual zero/span. However, if the zero/span sequence is running, stop the sequence by turning the pump on. This will return the system to normal EC mode. Then turn the pump off to enter manual zero/span mode.

Set **DO_P_offset** = **True.** This will turn all of the valves off and command the CPEC200 to measure the pressure offset. Watch the value of **press_offset**. Turning the pump on or setting **DO_P_offset = True** will reset this variable to zero. Within approximately 10 s after turning the pump off and setting **DO_P_offset = True**), **press_offset** will be set to the value of **cell_press** (with a 5 s moving average) and **DO_P_offset** will reset to **False**. Wait until **DO_P_offset = False** before proceeding.

Tip: The purpose of this step is for the CPEC200 to store the ambient pressure (measured by **cell_press** when there is no flow in the system) in public variable

press_offset. This allows the CPEC200 to infer the flow in the sample cell from the pressure rise resulting from the zero/span flow. Because ambient pressure changes over time (and the pressure sensor may drift over time), this pressure must be measured each time a zero/span is performed.

6.3.2.2 Checking and Setting the Zero

The keyboard display has menus to facilitate manual zero control for users that are onsite. Navigate:

Manual zero/span → Manual Control → H2O and CO2 Zero

Set **valve_number** to ZeroAir (1). If onsite, look at the LEDs on the valve module to confirm the selected valve is now active. Verify **valve_status** reports *Valve flow is OK*. If not, check the value of **valve_flow** and troubleshoot as needed.

Verify **cpec_status** reports *CPEC is OK*. If not, troubleshoot as needed.

NOTE There is no automatic error checking in full manual mode, so diagnostics must be checked manually.

Watch the values of CO_2 and H_2O. When they stabilize, set **DO_zero = True**. The IRGA will set its CO_2 and H_2O readings to zero. Verify the values of H_2O and CO_2 are near zero.

Set **valve_number** = **None** (0) to stop the flow of zero gas.

6.3.2.3 Checking and Setting the CO_2 Span

The keyboard display has menus to facilitate manual zero control for users that are onsite. Navigate:

Manual zero/span → Manual Control → CO2 Span

Set **valve_number** to one of the CO_2 span valves. If onsite, look at the LEDs on the valve module to confirm the selected valve is now active. Verify **valve_status** reports *Valve flow is OK*. If not, check the value of **valve_flow** and troubleshoot as needed.

NOTE The 3-valve module has only one CO_2 span valve available, **CO2span1**. The 6-valve module has three additional CO_2 span valves available.

Make sure the value in **CO2_SPAN_PPM** matches the CO_2 concentration of the CO_2 span cylinder you have selected.

Verify **cpec_status** reports *CPEC is OK*. If not, troubleshoot as needed.

NOTE There is no automatic error checking in full manual mode, so diagnostics must be checked manually.

Watch the values of CO_2 and H_2O. When they stabilize, set **DO_CO2_span = True**. The IRGA will set the CO_2 span to the value in **CO2_SPAN_PPM**. Verify the measured value **CO2** now matches the value of **CO2_SPAN_PPM**.

Set **valve_number** = **None** (0) to stop the flow of CO_2 span gas.

6.3.2.4 Checking and Setting the H_2O Span

H_2O is more difficult to span than CO_2 because it is more difficult to provide a source of air with known humidity. In most cases, a commercially available dewpoint generator is used.

The keyboard display has menus to facilitate manual zero control for users that are onsite. Navigate:

Manual zero/span → Manual Control → H2O Span

Set **valve_number** = **H2Ospan**. If onsite, look at the LEDs on the valve module to confirm the selected valve is now active. Verify **valve_status** reports *Valve flow is OK*. If not, check the value of **valve_flow** and troubleshoot as needed.

NOTE When the **H2Ospan** valve is selected, the CPEC200 does not control the flow. It opens the control valve completely to minimize pressure drop. The dewpoint generator determines the flow that it pushes to the EC155. The variable **valve_flow_OK** = **True** for any flow between 0.2 and 2.0.

Make sure the value in **H2OSpanDewPt** matches the setting of the dewpoint generator.

Verify **cpec_status** reports *CPEC is OK*. If not, troubleshoot as needed.

NOTE There is no automatic error checking in manual zero/span mode, so diagnostics must be checked manually.

Watch the values of **H2O**, **Td_cell**, and **Td_ambient**. All of these report the measured humidity. **H2O** is the raw H_2O concentration, in mmol mol^{-1}. **Td_cell** is the dewpoint temperature calculated by the CPEC200 system for the air in the sample cell (at the sample cell pressure). **Td_ambient** is similar to **Td_cell**, but it is calculated for ambient pressure. **Td ambient** and **Td_cell** should be very similar. If not, make sure the sample cell pressure is close to ambient pressure (**diff_press** is close to zero).

When **Td_cell** stabilizes, set **DO_H2O_span = True**. The IRGA will set the H_2O span to make the measured dewpoint **Td_cell** match **H2OSpanDewPt**. Verify that these two values now match.

Set **valve_number** = **None** (0) to stop the flow of H_2O span gas.

6.3.2.5 Returning to Normal EC Mode

When checking and setting are completed, turn the pump on by setting **pump_ON** = **True**. This will make sure the valves are turned off and restart the pump.

Disable temperature control of the valve module to conserve power (this is not done automatically in full manual control).

7. Maintenance and Troubleshooting

Most of the basic diagnostic and troubleshooting issues for the CPEC200 are covered in Appendix A, *CPEC200 Diagnostics*. The section that follows provides additional detail on some issues that may arise with hardware components.

7.1 Enclosure Desiccant

Check the humidity indicator card in the mesh pocket in the CPEC200 system enclosure door and the EC100 enclosure door. The humidity indicator card has three colored circles that indicate the percentage of humidity (see FIGURE 4-14). Desiccant packets inside the enclosure should be replaced with fresh packets when the upper dot on the indicator begins to turn pink. The indicator card does not need to be replaced unless the colored circles overrun.

CAUTION Campbell Scientific strongly suggests replacing desiccant instead of reactivating old desiccant. Improper reactivation can cause the desiccant packets to explode.

The replacement desiccant pack is the 4905 Single 4-Unit Silica Desiccant Bag which can be purchased in quantities of 20 as pn 6714. The replacement humidity indicator card is pn 28878. See Section 4.1.5, *Replacement Parts*, for more detail.

If the desiccant packs in the CPEC200 system enclosure are requiring frequent replacement, check that the feedthrough cap is properly installed. In very humid conditions it may be helpful to seal the cable feedthrough with plumber's putty as described in Section 5.3.4, *Apply Power*.

7.2 EC155 Intake Filter

Over time, the EC155's intake filter will become plugged with particulates from the air causing an increased pressure drop. The EC155 has a differential pressure sensor with a ±7 kPa range to measure the sample cell pressure with respect to ambient pressure. As the intake filter plugs over time, the differential pressure will decrease from approximately –3 kPa (typical for a clean filter at 7 LPM). If the differential pressure reaches –7 kPa, the data will no longer be valid. It is important to monitor the differential pressure and replace the filter before this limit is reached.

The default replacement filter is pn 26072. It is a 2.5-cm (1.0-in) diameter, sintered stainless steel disk filter of 20 µm pore size, with a molded Santoprene™ shell. An alternative 40 µm filter (pn 28698) is also available.

NOTE Choose the 40 µm filter if the default 20 µm filter clogs long before the EC155 optical windows become dirty.

See the *EC155 CO_2 and H_2O Closed-Path Gas Analyzer Manual* for details on replacing the intake filter.

7.3 EC155 Windows

Over time, the optical windows of the EC155 will become dirty and will need to be cleaned. To evaluate the cleanliness of the windows, monitor the CO_2 signal and the H_2O signal. These will have a value of approximately 1.0 for clean windows, but will decrease as the windows become dirty. The EC155 is calibrated for a range of signal levels down to 0.80. Clean the windows as instructed in the *EC155 CO_2 and H_2O Closed-Path Gas Analyzer Manual* before the CO_2 and H_2O signals reach 0.80.

7.4 EC155 Chemical Bottles

If more than one year has passed since replacing the desiccant/scrubber, or if zero-and-span readings have drifted excessively, the desiccant/scrubber bottles (pn 26511) within the EC155 analyzer head should be replaced as detailed in the *EC155 CO_2 and H_2O Closed-Path Gas Analyzer Manual*.

7.5 Pump Module Filter

In very humid conditions, water may condense and collect inside the housing of the filter that is located in the pump module enclosure. This is normal and will have no effect on the measurements. In most cases, the water will evaporate as ambient conditions change.

If, however, the water level rises such that the filter is more than half full, the situation can be alleviated by carrying out the following process.

Disconnect the pump tube from the outside of the fiberglass pump module enclosure (see FIGURE 5-5). Remove the enclosure from the mounting structure. Do not disconnect the filter housing or any connections inside the pump module enclosure. Leaving the enclosure closed, repeatedly rotate the entire pump module enclosure upside down and then right side up several times to drain the water through the inlet bulkhead fitting.

8. Repair

The CPEC200 is designed to give years of trouble-free service with reasonable care. However, if factory repair is needed, contact a Campbell Scientific application engineer to obtain an RMA number. An RMA number and product safety documents are required prior to any repair shipments being accepted at Campbell Scientific. See details in the *Assistance* section at the beginning of this document.

Consult with a Campbell Scientific application engineer to determine which parts or assemblies should be sent for repair. If the system enclosure is to be returned, plug the inlets and cap the ends of all tubes to keep debris out. Swagelok® caps and plugs have been provided for this purpose.

Appendix A. CPEC200 Diagnostics

A.1 Overview

CPEC200 diagnostic information is available to the user in any of three different formats: status text strings, status Boolean variables, and diagnostic flags encoded as binary bits in integer variables. With these multiple avenues of accessing the information, the CPEC200 diagnostics provide user-friendly real-time troubleshooting, statistics on individual error conditions, and a compact format for final storage tables.

A.2 Status Text Variables

There are several text-string variables that report the status of the CPEC200 system in real time. These are public variables that can be viewed onsite using the datalogger display. They may also be viewed remotely via *LoggerNet*, LoggerLink, or other applications if a communication link is available. The status text variables are not as comprehensive as the diagnostic flags, but they provide troubleshooting help for most of the issues that are likely to arise and can guide the user to the more advanced diagnostic information.

Status variables are not generally saved in the output tables because they take too much storage space. Each of these variables is described below.

latest_note

Public variable **latest_note** shows the latest message written to the **message_log** table. The **message_log** table stores a record that includes a text message as well as several variables that describe the state of the system when the record is written. It notifies the user of a significant event, such as a change to a configuration variable or events related to a zero/span sequence. After one minute the text in **latest_note** is marked as old, but is still displayed. See Appendix C, *Output Variables*, for more information on the **message_log** table.

mode_status

Public variable **mode_status** describes the basic operating state of the CPEC200. It correlates with Boolean variable **EC_mode**. If **EC_mode** = **True**, then **mode_status** will be *Normal EC mode*. If **EC_mode** = **False**, multiple messages may be given for **mode_status** depending on other factors. Boolean **EC_mode** is stored in the time series output table to allow the user to screen data for post-processing. For any outputs in which **EC_mode = False**, the corresponding record should not be included in eddy covariance calculations.

If the CPEC200 is not configured to use the valve module, there are only two possible values for **mode_status**:

- *Normal EC mode*: This indicates the pump is on (**pump_ON** = **True**)
- *Standby mode (Pump is Off)*: This indicates the pump is off (**pump_ON** = **False**)

If the CPEC200 program is configured for valve operation there are more possibilities:

- *Normal EC mode*: Pump is on
- *Manual Zero/Span mode*: Pump is off
- *Starting Zero/Span sequence*: This message persists normally for only one scan indicating the zero/span sequence has been triggered, either automatically or manually, but has not yet begun.
- If the zero/span sequence is active, **mode_status** describes the current step in the sequence as shown in TABLE 6-1, found in Section 6.2, *Automatic Zero and Span*.

cpec_status

Public variable **cpec_status** gives an overall status for the entire system. If there are no problems detected, **cpec_status** will report *CPEC is OK*. This is equivalent to diagnostic word **diag_cpec = 0**. In most cases where a problem is detected, **cpec_status** refers the user to a lower-level (subsystem) status variable such as **irga_status**, **sonic_status**, **pump_status**, or **valve_status** which are described in the sections below.

- *CPEC is OK* means there are no relevant errors detected. This is equivalent to **diag_cpec = 0** (no bits set)
- *ERROR: Battery voltage is in deadband* or *ERROR: Battery voltage is too low* means there is a problem with the supply voltage. This is equivalent to **BattVolt_OK = False** and **diag_cpec** bit 9. See the notes for bit 9.
- *ERROR: IRGA problem* is equivalent to **diag_cpec** bit 8. See notes on **irga_status**.
- *ERROR: Sonic problem* is equivalent to **diag_cpec** bit 7. See notes on **sonic_status**.
- *ERROR: Pump flow problem* is equivalent to **diag_cpec** bit 6. See notes on **pump_status**.
- *ERROR: Pump temperature problem* is equivalent to **diag_cpec** bit 5. See notes on **pump_status**.
- *WARNING: Buffer depth too large* is equivalent to **diag_cpec** bit 4. See the notes on bit 4, **buff_depth_OK**.
- *ERROR: Valve flow problem* is equivalent to **diag_cpec** bit 3. See notes on **valve_status**.
- *ERROR: Valve temperature problem* is equivalent to **diag_cpec** bit 2. See notes on **valve_status**.
- *ERROR: Scrub module temperature problem* is equivalent to **diag_cpec** bit 1. See notes on **valve_status**.

irga_status

Public variable **irga_status** gives the status of the EC155 and is based on the diagnostic word from the EC155 (**diag_irga**) as well as the CO_2 and H_2O signal levels, which do not trigger a diagnostic bit in the EC155.

- *IRGA is OK* is displayed if bit one of **diag_irga** is zero and the CO_2 and H_2O signals are both greater than 0.8. This means the EC155 has detected no problems and the EC155 windows are clean.
- *ERROR: No data from IRGA - Check EC100 power and communication* is displayed if **diag_irga** = **NAN**. This indicates the EC100 does not respond to the datalogger's request for data, usually

because the EC100 is not powered, or the SDM cable from the datalogger to the EC100 is not connected.

- *ERROR: No EC155 detected - Check EC155 connections to EC100* is displayed if **diag_irga** = **–1** (all diagnostic bits are set). This usually means the EC155 sensor head is not connected to the EC100.
- If bit 9 of **diag_irga** is set, this indicates the EC155 has been powered down. There are multiple possible causes and each has a different message reported in **irga_status**:
  - *ERROR: IRGA is OFF - Check BattVolt* is displayed if **BattVolt_OK** = **False**. This usually means the EC155 has been powered down by the CPEC200 because the battery voltage has dropped below the shutdown limit.
  - *ERROR: IRGA is OFF - Check source_tmpr* is displayed if **BattVolt_OK** = True and bit 7 of **diag_irga** is set. This usually indicates the EC155 has powered itself down because the internal temperature, **source_tmpr**, is outside its operating range. The EC155 will power itself off if **source_tmpr** rises above 55 °C, and will not turn back on until the temperature drops to 50 °C. At cold temperatures, the EC155 will power off at –35 °C and back on at –30 °C.
  - *ERROR: IRGA is OFF* is displayed if the EC155 is powered down for an unknown reason.
- *IRGA is starting up* is displayed if bit 3 of **diag_irga** is set. This normally indicates the EC100 has just been powered up or the EC155 has been turned on. It may take a few minutes for the IRGA to start up and report data.
- *ERROR: diff_press problem - Check intake filter* is displayed if bit 23 of **diag_irga** is set. Normally, this indicates the EC155 intake filter has plugged, which causes a pressure drop in the EC155 greater than the differential pressure sensor's ± 7 kPa range.
- *ERROR: CO2 signal is too low - Check EC155 windows* is displayed when the CO_2 signal level is below 0.8. This normally indicates the EC155 windows have become dirty and should be cleaned.
- *ERROR: H2O signal is too low - Check EC155 windows* is displayed when the H_2O signal level is below 0.8. As with CO_2 signal level, this normally indicates the EC155 windows have become dirty and should be cleaned.
- *ERROR: IRGA problem - Check diag_irga* is displayed when some other bit is set in **diag_irga**. See the EC155 user manual for further troubleshooting suggestions.

sonic_status

Public variable **sonic_status** gives the status of the sonic anemometer and is based on the diagnostic word from the CSAT3A (**diag_sonic**).

- *Sonic is OK* is displayed if **diag_sonic** = **0**. This means the CSAT3A has detected no problems.
- *ERROR: No data from sonic - Check EC100 power and communication* is displayed if **diag_sonic** = **NAN**. This indicates the EC100 does not respond to the datalogger's request for data, usually because the EC100 is not powered, or the SDM cable from the datalogger to the EC100 is not connected.
- *ERROR: No CSAT3A detected - Check CSAT3A connections to EC100* is displayed if **diag_sonic** = **–1** (all diagnostic bits are set).

This usually means the CSAT3A sensor head is not connected to the EC100.

- *ERROR: Sonic problem - Check diag_sonic* is displayed when a bit is set in **diag_sonic**. This usually means the sonic path is blocked. If there is no obvious reason for the problem, such as water on the face of a transducer, contact Campbell Scientific for assistance.

pump_status

Public variable **pump_status** gives the status of the pump and is based on the state of several variables.

- *Pump is OK* is displayed if the pump flow is within 10% of the setpoint (**pump_flow_OK = True**).
- *Pump is OFF - Set pump_ON = True to restart it* is displayed if the pump is turned off (**pump_ON = False**). This is not necessarily an error condition. It normally arises when the user intentionally turns the pump off to perform a manual zero/span, for example. For this reason, this condition does not set a bit in **cpec_diag**.
- *ERROR: Pump is disabled - Check BattVolt* is displayed if the battery voltage has dropped below the minimum and the CPEC200 has disabled the pump. This correlates with **BattVolt_OK** = **False**. See notes for bit 9.
- *ERROR: Pump is disabled - Check pump_tmpr* is displayed if the pump temperature is outside its operating range. This correlates with **pump_tmpr_OK = False**. See notes for bit 5.
- *ERROR: Pump is disabled - IRGA is OFF* is displayed if the CPEC200 has stopped the pump because the IRGA is off. This correlates with **irga_OFF = True** and could be a result of the EC155 automatically powering down because its source temperature is outside its operating range. See the EC155 manual for details.
- *ERROR: Pump flow is NAN* is displayed if **pump_flow = NAN.** This indicates a problem with the pump speed measurement. See notes on bit 6.
- *ERROR: Pump flow is not at setpoint - Check buff_depth* is displayed if the pump flow is not within 10% of the setpoint (**pump_flow_OK = False**) and the processing has fallen too far behind (**buff_depth_OK = False**). A processing delay does not always cause a pump flow error. In many cases, the processing will catch up before the pump flow drifts too far from the setpoint. For additional information see notes on bit 4.
- *ERROR: Pump flow is not at setpoint* is displayed if the pump flow is too far from the setpoint and the problem cannot be explained by one of the conditions listed above. For additional troubleshooting advice, see notes on bit 6.

valve_status

Public variable **valve_status** gives the status of the optional valve module (either the three- or six-valve module) and is based on the state of several variables.

If the program is not configured to use the optional valve module (constant **VALVE_MODULE** = **False**), then **valve_status** will always display *Program not configured for valve operation - Set VALVE_MODULE = True and recompile*. See Section 5.4.2, *Compile Switches*, for details on configuring the CPEC200 program for valve module operation.

If the program is configured to use the valve module (constant **VALVE_MODULE** = **True**), but the valves are not being used (**valve_number** = **0**), there are several possible values for **valve_status** that relate to the temperature of the valve module. **valve_status** also depends on the temperature of the optional scrub module if it is installed. See notes on bits 2 and 1 for more information on valve module and scrub module temperature control.

- *Valves are in standby mode (temperature control is disabled)* is displayed if valve module temperature control is disabled (**valveTctl_ON** = **False**). This is the normal state for the valve module when it is not in use.

The rest of the possible values for **valve_status** given below, apply only when valve module temperature control is enabled.

- *Valves are ready* is displayed if the valve module temperature is within its operating range and the scrub module (if installed) temperature is also within its operating range.
- *Valves are too cold* is displayed if the valves are below the minimum operating temperature. See notes on bit 2.
- *Valves are too warm* is displayed if the valves are above the maximum operating temperature. See notes on bit 2.
- *Valve temperature problem* is displayed if the valve temperature is not defined (NAN). See notes on bit 2.
- *Scrub module is too cold* is displayed if the valve module is within its operating range, but the scrub module is too cold. See notes on bit 1.
- *Scrub module is too warm* is displayed if the valve module is within its operating range, but the scrub module is too warm. See notes on bit 1.
- *Scrub module temperature problem* is displayed if the scrub module temperature is not defined (NAN). See notes on bit 1.

If a valve has been selected (**valve_number** > **0**), there are several possible values for **valve_status.**

- *Valve flow is OK* is displayed if the valve flow is within an acceptable range (**valve_flow_OK = True**).
- *ERROR: Valves are disabled - Check BattVolt* is displayed if the battery voltage has dropped below the minimum and the CPEC200 has disabled the valves. This correlates with **BattVolt_OK** = **False**. See notes for bit 9.
- *ERROR: Valves are disabled - IRGA is OFF* is displayed if the CPEC200 has disabled the valves because the IRGA is off. This correlates with **irga_OFF = True** and could be a result of the EC155 automatically powering down because its source temperature is outside operating range. See the *EC155 CO_2 and H_2O Closed-Path Gas Analyzer Manual* for details.
- *ERROR: press_offset is zero - turn pump off and set DO_P_offset = true* is displayed if **press_offset** = **0**. The CPEC200 requires a recent measurement of the pressure offset which is given as the sample cell pressure measured with no flow. The pressure offset is set to zero when it is no longer valid. A new measurement of the pressure offset can be achieved by turning, the pump off and setting **DO_P_offset = True**. See Section 4.2.3, *Valve Module*, for more details on how the

pressure sensor is used to infer flow, and Section 6.3.2, *Full Manual Control of Zero and Span*, for more detailed information about how the pressure offset is measured.

- *ERROR: Valve flow is NAN* is displayed if **press_offset** is not zero and valve**_flow = NAN** (see the note above for the case when **press_offset** = **0**). This indicates a problem with the valve flow measurement. See notes on bit 3 for details.
- *ERROR: Valve flow is not at setpoint - Check buff_depth* is displayed if the valve flow is outside the acceptable range (**valve_flow_OK = False**) and the processing has fallen too far behind (**buff_depth_OK = False**). A processing delay does not always cause a valve flow error. In some cases, the processing may catch up before the valve flow drifts too far from the setpoint. For additional information see notes on bit 4.
- *ERROR: Valve flow is not at setpoint* is displayed if the valve flow is outside the acceptable range and the problem cannot be explained by one of the conditions listed above. For additional troubleshooting advice, see notes on bit 3.

A.3 Status Boolean Variables

CPEC200 status information is also provided as discrete Boolean variables that indicate whether or not a particular subsystem has a problem. Most of these variables have names that end in "OK." These variables are intended to bridge the gap between the user-friendly "status text variables" and the compact yet cryptic "diagnostic words." They provide an intermediate level of information for real-time troubleshooting and allow the CPEC200 to store statistics on various conditions.

EC_mode

This Boolean variable is intended for screening time-series data for post-processing. **EC_mode** = **True** if the sample pump is on and no zero/span sequence is running (see Section A.2, *Status Text Variables*). Records for which **EC_mode** = **False**, should be excluded from EC calculations. This variable is also used by the CPEC program to determine the relevance of some of the error conditions. For example, the pump flow is relevant only in EC mode, but the battery voltage is always relevant. This relevance based on **EC_mode** determines whether or not a particular bit will be set in **diag_cpec** (see Section A.2, *Status Text Variables*, for details).

BattVoltOK

Boolean variable **BattVoltOK** is equivalent to bit 9 of **diag_cpec**. If **BattVoltOK** is false, this indicates the CPEC200 supply voltage has fallen below the shutdown limit and has not risen to an acceptable restart level. See notes on bit 9.

irga_OK

Boolean variable **irga_OK** is equivalent to bit 8 of **diag_cpec**. If an IRGA problem is detected, **irga_OK** = **False** and bit 8 of **diag_cpec** will be set. See notes on bit 8 and on **irga_status**, which may give additional information about the IRGA problem.

sonic_OK

Boolean variable **irga_OK** is equivalent to bit 8 of **diag_cpec**. If an IRGA problem is detected, **irga_OK** = **False** and bit 8 of **diag_cpec** will be set. See

notes on bit 8 and on **irga_status**, which may give additional information about the IRGA problem.

pump_flow_OK

Boolean variable **pump_flow_OK** = **True** if the pump flow (**pump_flow)** is within 10% of the setpoint **PUMP_SETPT.** It is set to **False** if it is outside this range.

The **PUMP_SETPT** check is performed continuously and **pump_flow_OK** is set accordingly. If the CPEC200 is in EC mode and **pump_flow_OK** is **false**, bit 6 of **diag_cpec** will be set to indicate there is a problem with the pump flow. If the CPEC200 is not in EC mode, **pump_flow_OK** is ignored. See notes on bit 6.

pump_tmpr_OK

Boolean variable **pump_tmpr_OK** = **True** if the pump is within its range (0 to 55 °C) and is set to **False** if it is outside this range.

This check is performed continuously, and **pump_tmpr_OK** is set accordingly. If the CPEC200 is in EC mode, bit 5 of **diag_cpec** will be set if **pump_tmpr_OK** = **False** to indicate there is a problem with the pump temperature. If the CPEC200 is not in EC mode, **pump_tmpr_OK** is ignored. See notes on bit 5.

buff_depth_OK

Boolean variable **buff_depth_OK** is equivalent to bit 4 of **diag_cpec**. If the datalogger processing falls too far behind, **buff_depth_OK** =**False** and bit 4 of **diag_cpec** will be set. See notes on bit 4.

valve_flow_OK

Boolean variable **valve_flow_OK** is defined only if the CPEC program is configured to use a valve module. See Section, 4.2.3, *Valve Module*, for details.

If the valve (zero/span) flow (**valve_flow)** is within its normal range, **valve_flow_OK** = **True** but = **False** if it is outside this range. This check is performed only if a valve is selected (**valve_number** > **0**).

The variable **valve_flow_OK** is ignored in EC mode, but if the CPEC200 is not in EC mode, bit 3 of **diag_cpec** will be set if **valve_flow_OK** = **False** to indicate there is a problem with the valve flow. See notes on bit 3.

valve_tmpr_OK

Boolean variable **valve_tmpr_OK** is defined only if the CPEC program is configured to use a valve module. See Section 4.2.3, *Valve Module*, for details.

If the valve module temperature **valve_tmpr** is within its operating range (0 to 60 °C), **valve_tmpr_OK** = **True** but will = **False** if it is outside this range. This check is performed continuously, and Boolean variable **valve_tmprOK** is set accordingly.

The variable **valve_tmpr_OK** is ignored in EC mode, but if the CPEC200 is not in EC mode, bit 2 of **diag_cpec** will be set if **valve_tmpr_OK= False, i**ndicating there is a problem with the temperature of the valve module. See notes on bit 2.

scrub_tmpr_OK

Boolean variable **scrub_tmpr_OK** is defined only if the CPEC program is configured to use a scrub module. See Appendix G, *CPEC200 Scrub Module Installation, Operation and Maintenance*, for details.

If **scrub_tmpr_OK** = **True,** the scrub module temperature (**scrub_tmpr)** is within its operating range (5 to 50 °C). It is set to **False** if it is outside this range. This check is performed continuously and Boolean variable **scrub_tmprOK** is set accordingly.

The variable **scrub_tmpr_OK** is ignored in EC mode, but if the CPEC200 is not in EC mode, bit 1 of **diag_cpec** will be set if **scrub_tmpr_OK** = **false**, indicating there is a problem with the temperature of the scrub module. See notes on bit 1.

A.4 CPEC200 Diagnostic Words

The CPEC200 has three diagnostic words that encode multiple error conditions as binary bits. These diagnostic words are more difficult to interpret than the status text variables, but they are more comprehensive and require very little storage space. They are stored in the time-series output table instead of the text-based status messages or as individual Boolean variables. The three diagnostic words are **diag_sonic**, **diag_irga,** and **diag_cpec**. The diagnostic words **diag_sonic** and **diag_irga** are sent directly from the EC100 and are only partially decoded within the CPEC200 program as needed to affect other variables. They are stored in the time series output table for troubleshooting in post processing. For a complete listing of the diagnostic bits encoded by these words, see the *EC155 CO_2 and H_2O Closed-Path Gas Analyzer Manual*.

Diagnostic word **diag_cpec** flags several conditions specific to the normal operating range for the CPEC200. Some of these conditions may or may not be relevant, depending on if the CPEC200 is in **EC mode**. The diagnostic word **diag_cpec**, includes only the diagnostic flags that are relevant depending on **EC_mode**. Any value other than zero for **diag_cpec** indicates a problem in the present mode. TABLE A-1 lists each of the diagnostic flags, including which mode it applies to.

To diagnose a problem when **diag_cpec** is any number other than zero, the value is decoded according to TABLE A-1 and additional information is available in the corresponding sections below. A user unfamiliar with converting a decimal number to binary, may find it convenient to use a decimal-to-binary converter that can be found on the Internet. Alternately, follow the step-by-step troubleshooting instructions as a guide through the conversion process.

TABLE A-1. Summary CPEC200 diagnostic flags encoded in diag_cpec					
Binary Bit (LSB = 1)	**Numeric Value**	**Relevant?**		**Corresponding public variable (bit is set if variable=false)**	**Status reported in cpec_status**
		EC_mode = True	**EC_mode = False**		
9	256	Yes	Yes	BattVolt_OK	ERROR: Battery voltage is in deadband or ERROR: Battery voltage is too low
8	128	Yes	Yes	irga_OK	ERROR: IRGA problem
7	64	Yes	No	sonic_OK	ERROR: Sonic problem
6	32	Yes	No	pump_flow_OK	ERROR: Pump flow problem
5	16	Yes	No	pump_tmpr_OK	ERROR: Pump temperature problem
4	8	Yes	Yes	buff_depth_OK	WARNING: Buffer depth too large
3	4	No	Yes	valve_flow_OK	ERROR: Valve flow problem
2	2	No	Yes	valve_tmprOK	ERROR: Valve temperature problem
1	1	No	Yes	scrub_tmprOK	ERROR: Scrub module temperature problem
none	0	NA	NA	NA	CPEC is OK

Bit 9: Battery Voltage

If **diag_cpec** is greater than 255, this indicates bit 9 of **diag_cpec** is set. To decode other diagnostic bits, subtract 256 from **diag_cpec** and compare the remainder to the bit values below.

Bit 9 of **diag_cpec** is equivalent to **BattVolt_OK = False**. It indicates the power source for the CPEC200 has dropped below the acceptable voltage limit. This triggers the CPEC200 to power down as much of the system as possible to prevent a deep discharge that might damage the user's battery. The pump, valves, EC155 gas head, scrub module, and their associated fans, heaters and pumps will all be powered down. The EC100 electronics and the CSAT3A sonic head will remain powered, however. The CPEC200 will power back up when the supply voltage reaches an acceptable level.

There are two system configuration variables; **BATT_LOWLIMIT** and **BATT_DEADBAND** that determine the shutdown and turn-on voltage (see Section 5.4.1, *System Configuration Variables*).

BattVolt_OK will be set to **False** if the battery voltage **BattVolt** falls below the shutdown limit:

BattVolt < BATT_LOWLIMIT

Note that **BattVolt_OK** will remain **False** until the supply voltage reaches the turn-on voltage:

BattVolt > BATT_LOWLIMIT + BATT_DEADBAND

The purpose of the deadband (the gap between the shutdown voltage and the turn-on voltage) is to protect the CPEC200 from repeated power cycles when the battery voltage is very near the shutdown limit.

There are two possible values for **cpec_status** when **BattVolt_OK** = **False**. If the battery voltage is below the shutdown limit, **cpec_status** will report *ERROR: Battery voltage is too low.* In this case, the battery must be recharged before the CPEC200 will resume normal operation.

If **BattVolt_OK** = **False** and the battery voltage is in the deadband, **cpec_status** will report *ERROR: Battery voltage is in deadband.* This situation can arise if the battery voltage was previously below the shutdown limit causing the CPEC200 to set the battery voltage error flag and shut the system down. Subsequently the battery voltage recovered enough to be in the deadband (above the shutdown limit but below the turn-on limit).

If **BattVolt_OK** = **False** and **BattVolt** is in the deadband, manually set **BattVolt_OK** = **True** which may allow the CPEC200 to power up. However, the increased current drawn upon powerup may cause the battery voltage to fall below the shutdown limit causing the CPEC200 to shut down again. In this case, the battery may need to be further recharged.

The voltage at the CPEC200 power input terminals can also be measured and compared to **BattVolt**.

NOTE **BattVolt** is measured in the datalogger which has a diode for reverse voltage protection. The actual voltage at the input terminals will be approximately 0.3V higher than the value reported by **BattVolt**.

The CPEC200 supply voltage must be 10.5 Vdc to 16.0 Vdc. See Section 4.3, *Specifications*, for details on the power required, especially the extra power required for a cold startup.

Bit 8: IRGA

If the remainder of **diag_cpec** (after subtracting the numeric value for higher bits that are set) is greater than 127, this means that bit 8 of **diag_cpec** is set. To decode other diagnostic bits, subtract 128 from **diag_cpec** and compare the remainder to the bit values below.

Bit 8 of **diag_cpec** is equivalent to **irga_OK** = **False**. This indicates either a diagnostic has been set in the EC100 or that the signal levels are too low:

1. Check the value of **diag_irga**. If it is NAN, this indicates the CR3000 is not receiving data from the EC100. Check the SDM cable connection between the EC100 and the CR3000, and make sure power is supplied to the EC100.

2. If **diag_irga** is **–1**, this indicates the EC100 does not recognize that an IRGA is connected. Make sure the EC155 sensor head cable is connected to the EC100. (Remove power from the EC100 before connecting or disconnecting the EC155).

3. If **diag_irga** is a number greater than zero, this indicates the EC100 has detected a problem. Troubleshoot per the *EC155 CO_2 and H_2O Closed-Path Gas Analyzer Manual*.

If **diag_irga** is zero, this means the EC100 has detected no errors with the EC155. However, the EC100 does not check for low signal levels. Check the values of **CO2_signal** and **H2O_signal**. These variables give a relative signal level at the EC155 detector. These variables should be approximately 1.0 for clean windows. As the windows become dirty, these signals will drop. If either of these signals is below 0.80, **irga_OK** will be set to **False** and the EC155 source and detector windows should be cleaned per the *EC155 CO_2 and H_2O Closed-Path Gas Analyzer Manual*.

Bit 7: Sonic Anemometer

If the remainder of **diag_cpec** (after subtracting the numeric value for higher bits that are set) is greater than 63, this means that bit 7 of **diag_cpec** is set. To decode other diagnostic bits, subtract 64 from **diag_cpec** and compare the remainder to the bit values below.

Bit 7 of **diag_cpec** is equivalent to **sonic_OK = False**. It indicates there is a problem with the sonic anemometer. Troubleshoot as follows:

1. Check the value of **diag_sonic**. If it is NAN, this indicates the CR3000 is not receiving data from the EC100. Check the SDM cable connection and make sure power is supplied to the EC100.

2. If **diag_sonic** is –1, this indicates the EC100 does not recognize that a CSAT3A sonic head is connected. Make sure the CSAT3A cable is connected to the EC100. (Remove power from the EC100 before connecting or disconnecting the CSAT3A).

3. If **diag_sonic** is a number greater than zero, check that the sonic path is not blocked. If no obvious reason for the problem (such as water on the face of a transducer) can be found, contact Campbell Scientific for assistance.

Bit 6: Pump Flow

If the remainder of **diag_cpec** (after subtracting the numeric value for higher bits that are set) is greater than 31, this means that bit 6 of **diag_cpec** is set. To decode other diagnostic bits, subtract 32 from **diag_cpec** and compare the remainder to the bit values below.

Bit 6 of **diag_cpec** indicates the pump flow is not at the setpoint. To confirm the problem, verify that public variable **pump_flow_OK** = **False**. This variable is set to true if the value of **pump_flow** matches **PUMP_SETPT** within 10%. It is set to false if it is outside this range. If the pump is turned off this check is still performed, but is not relevant. (**pump_flow_OK** = **False**, but bit 6 **diag_cpec** will not be set.)

If the value of **pump_flow** = **NAN**, this indicates a problem with the pump speed measurement. Contact Campbell Scientific for assistance.

If the flow is not at the setpoint, check the value of **pump_control**. This variable controls the speed of the pump, from 0.0 (off) to 1.0 (full speed). In normal operation, when the flow falls below the setpoint, the CPEC200 will

respond by increasing **pump_control**. This should increase the speed of the pump and allow **pump_flow** to rise to the setpoint. Conversely, if the flow is above the setpoint the CPEC200 will adjust **pump_control** downward until the flow matches the setpoint.

If **pump_control** = **0**, this indicates the CPEC200 has turned the pump off. There are several reasons the CPEC200 may shut the pump off:

- Low supply voltage (see notes on bit 9)
- IRGA has been powered down (see notes on bit 8)
- Pump temperature out of range (see notes on bit 5)
- Pump has been turned off by the user. If public variable **pump_ON = False**, then set **pump_ON = True** to turn the pump on

If the pump flow is too low and **pump_control** is greater than 0, then verify the pump is running. If the CPEC200 is physically accessible, listen for the sound of the pump to confirm it is running. Note that the pump is very quiet, especially at lower pumping speeds, and may be hard to hear in noisy environments. If the CPEC200 is remotely located, confirm that the pump is running by turning the pump on and off and checking the value of **pump_press**. If the pump is running, it will pull this pressure down below ambient pressure. The pressure drop will vary depending on conditions, but 3 kPa is typical for a clean intake filter at the default flow of 7 LPM. If the pressure drop is significantly smaller than is typical, make sure the pump tube is connected between the EC155 and the pump module.

If the pressure does not vary when the pump is turned on and off, it is likely the pump is not running. If the pressure changes, but the value of **pump_flow** does not, it is likely that the pump is actually running but there may be a problem with the pump speed measurement. Contact Campbell Scientific in either case.

If the pump is running, but the value of **pump_control** does not change as expected to control the flow, make sure that datalogger processing is not lagging (see notes on bit 4).

Bit 5: Pump Temperature

If the remainder of **diag_cpec** (after subtracting the numeric value for higher bits that are set) is greater than 15, this means that bit 5 of **diag_cpec** is set. To decode other diagnostic bits, subtract 16 from **diag_cpec** and compare the remainder to the bit values below.

Bit 5 of **diag_cpec** indicates the pump temperature is outside its operating range. This triggers the CPEC200 to shut down the pump to protect the pump from possible damage. This check is performed even if the pump is turned off.

To confirm the problem, verify that public variable **pump_tmpr_OK = False**. This variable is set to **True** if the valve temperature is within its operating range (0 to 55 °C) and is set to **False** if it is outside this range.

The variable **pump_tmpr_OK** is not available for diagnosing a problem using data saved in the output tables (**Flux** or **Zero_Span)**. Instead, check the value of **PumpTmprOK_Avg**. This is a floating point number that represents the fraction of time (from 0 to 1) that **pump_tmpr_OK** is true during the averaging period. A value of 1 indicates no pump temperature problem at any

time during the averaging period. A value of 0 indicates a pump temperature problem during the entire time.

To continue troubleshooting a problem with the pump temperature, check the measured pump temperature, **pump_tmpr**. If it is NAN, this indicates a problem with the temperature measurement. Make sure the pump module cable is connected to the "Pump Module" connector on the bottom of the CPEC200 system enclosure.

Next, compare **pump_tmpr** to the operating range (0 to 55 °C). The pump will be disabled if the pump is too cold. The pump module has a heater that turns on if **pump_tmpr** falls below 2 °C. If the pump temperature is too low, check the operation of the heater which is controlled by public variable **pump_heat_ON**. For diagnosing a problem using data saved in the output table, **ts_data**, the state of fans and heaters is encoded into variable **ControlBits** to conserve memory space. See Appendix D, *Control Bits*. This value is saved only if saving all diagnostics. Its corresponding variable, **pump_heat_Avg,** is saved in the averaged output tables (**Flux** and **Zero_Span**). If the heater is on and the pump is too cold, check the ambient temperature. The CPEC200 is rated for temperatures from –30 to 50 °C. If the system is started in cold weather after being turned off for several hours, it may take up to 50 minutes to warm up to operating temperature.

The pump will also be disabled if the pump is too warm (above 55 °C). The pump module has a fan that turns on if **pump_tmpr** rises above 45 °C. The fan will stay on until the pump temperature falls below 40 °C. If the pump temperature is too high, check the operation of the fan which is controlled by public variable, **pump_fan_ON**. For diagnosing a problem using data saved in the output table, **ts_data**, the state of fans and heaters is encoded into variable, **ControlBits**, to conserve memory space. See Appendix D, *Control Bits*. This value is saved only if saving all diagnostics. Its corresponding variable **pump_fan_Avg** is saved in the averaged output tables (**Flux** and **Zero_Span**).

If the fan is on and the pump temperature is too high, check the ambient temperature. The CPEC200 is rated for ambient temperatures from –30 to 50 °C.

Bit 4: Pipeline Buffer Depth

If the remainder of **diag_cpec** (after subtracting the numeric value for higher bits that are set) is greater than 7, this means that bit 4 of **diag_cpec** is set. To decode other diagnostic bits, subtract 8 from **diag_cpec** and compare the remainder to the bit values below.

The CPEC200 CRBasic program runs in pipeline mode. This allows processing tasks to fall behind, but ensures that measurements always happen at the proper time. Generally, it is acceptable for processing tasks to fall behind occasionally, unless they include real-time control functions. For example, pipeline mode allows the flux calculations, which occur at the end of each half-hour averaging period, to take more time than is available in a single measurement scan interval. Processing instructions may be delayed by a few scans until the extra processing is completed. In this case, the actual measurements occur on time and are saved in a buffer until they can be processed. See the *CR3000 Micrologger Operator's Manual* for more information on pipeline mode.

Conversely, processing tasks that affect real-time control functions may be adversely affected if there are processing delays. The control algorithms that adjust the pumping speed and valve flow are processing tasks. If the datalogger processing is delayed these algorithms will use "old" measurements. This will cause the pump speed or valve flow to be poorly controlled.

The datalogger reports how far behind the processing task is in the public variable **buff_depth** (this is a copy of the variable **BuffDepth** from the Status table; more details can be found in the *CR3000 Micrologger Operator's Manual*). The processing delay is given as the number of datalogger measurement scans. If the buffer depth exceeds 10 scans (a one second delay for 100 ms scan interval), the control algorithms are disabled, public variable **buff_depth_OK** = **False**, and diagnostic bit 4 is set. The control algorithms will be disabled until the processing task can catch up to within 10 scans.

While all of the other diagnostic flags indicate conditions that make the measurements invalid, this is not necessarily the case with **buff_depth_OK**. For post-processing time-series data, it may be acceptable to use data with **buff_depth_OK** = **False**, as long as the pump flow (or valve flow, if in Zero/Span mode) is within range. In this case, the **buff_depth_OK** diagnostic can be considered a "warning" rather than an "error". There are, however, two other consequences to this flag. First, flagged data will not be included in the on-line EC calculations, and, second, it will cause an automatic zero or span to be aborted. Given this, the CPEC200 CRBasic program should be edited with care and measurement or processing tasks that cause excessive delay should not be added.

Bit 3: Valve Flow

If the remainder of **diag_cpec** (after subtracting the numeric value for higher bits that are set) is greater than 3, this means that bit 3 of **diag_cpec** is set. To decode other diagnostic bits, subtract 4 from **diag_cpec** and compare the remainder to the bit values below.

Bit 3 of **diag_cpec** indicates the valve flow is not at the setpoint. To confirm the problem, verify that public variable **valve_flow_OK** = **False**. This variable is set to true if the value of **valve_flow** is within an acceptable range. The criteria used to set this flag depend on several other variables.

If no valve is selected (**valve_number** = **0**), then the valve flow is not defined. In this case, **valve_flow** is set to zero and **valve_flow_OK** = **True**.

If a valve is selected, in most cases the valve flow should match the setpoint within 10%. There are two exceptions to this rule. First, if the H_2O span valve (6) is selected, the flow is controlled by dewpoint generator rather than the CPEC200 system. The dewpoint generator pushes flow through the valve module to the IRGA. The CPEC200 fully opens the flow control valve by setting **valveControl** = **1**. The acceptable range for **valve_flow** is between 0.2 and 2.0 LPM.

The second exception is when the flow is controlled by the scrub module and the **ZeroAir** valve (1) is selected. The scrub module has a pump to push the zero air through the valve module to the IRGA. The CPEC200 fully opens the flow control valve by setting **valveControl** = **1**. The acceptable range for **valve_flow** is between 0.5 and 3.0 LPM.

If the value of **valve_flow** = **NAN**, this indicates a problem with the valve flow measurement. The valve flow is inferred from the pressure drop in the sample cell as described in Section 4.2.3, *Valve Module*.

Check the value of **valveControl**. This variable determines the size of the opening of a proportional control valve, from 0 (fully closed) to 1.0 (fully open). This proportional control valve can be described as an electrically operated needle valve. In normal operation, when the flow falls below the setpoint, the CPEC200 will respond by increasing **valveControl**. This increases the opening in the proportional control valve and allows **valve_flow** to rise to the setpoint. Conversely, if the flow is above the setpoint the CPEC200 will adjust **valveControl** downward until the flow matches the setpoint.

If **valveControl** = **0**, this indicates the CPEC200 has turned the valve flow off. There are several reasons the CPEC200 may shut the valve flow off:

- No valve is selected
- Measured valve flow is NAN
- Low supply voltage (see notes on bit 9)
- IRGA has been powered down (see notes on bit 8)

If the flow is not at the setpoint, the troubleshooting steps depend on the situation. There are three cases:

1. Flow is provided from a cylinder of compressed gas. This is the most common situation. Make sure the cylinder's regulator is connected to the proper fitting on the valve module and that it is regulating the pressure to 10 ± 5 psig. The value of **valveControl** should be between 0.2 and 1.0. If **valveControl** = **0.2** and **valve_flow** is too high, this indicates the control valve is unable to provide enough restriction to limit the flow.

NOTE The proportional control valve will be fully closed at any value of **valveControl** below approximately 0.3.

   If **valveControl** is **1.0** and the flow is too low and the CPEC200 is accessible, check the indicator lights on the valve module. One of the inlet valve lights (*Zero Air*, *CO_2 Span 1*, etc.) should be illuminated. The *Flow Control* light should also be illuminated. The brightness of the *Flow Control* light indicates how hard the proportional control valve is driven. If **valveControl** = **1.0** this light should be full brightness (approximately as bright as the light that indicates which inlet valve is selected). If the appropriate valve module indicator lights are not illuminated, make sure the connector on the side of the valve module is connected.

2. If the H_2Ospan valve (6) is selected, the flow is not controlled by the CPEC200 system, but by the dewpoint generator, which pushes flow through the valve module to the IRGA. The CPEC200 fully opens the flow control valve by setting **valveControl** = **1**. The acceptable range for **valve_flow** is between 0.2 and 2.0 LPM. If the CPEC200 is accessible, check the indicator lights on the valve module as described above. Also check the tubing connection between the dewpoint

generator and the **Valve Module** inlet. Make sure there is no tee in this connection (see Section 5.2.2, *Zero/Span*). Finally, check the flow setting of the dewpoint generator.

3. If the **Zero Air** valve (1) is selected and a scrub module is used, the flow is controlled by the scrub module. The scrub module has a pump to push the zero air through the valve module to the IRGA. The CPEC200 fully opens the flow control valve by setting **valveControl = 1**. The acceptable range for **valve_flow** is between 0.5 and 3.0 LPM. If the CPEC200 is accessible, check the indicator lights on the valve module as described above. Also check the tubing connection between the scrub module and the valve module inlet. Listen for the sound of the scrub module pump to make sure it is running. Check the scrub module pressure **scrub_press**. This pressure is measured at the outlet of the scrub pump. This pressure is normally 3 to 20 kPa. If the pressure is very high, it might indicate the **Zero Air** valve or the proportion control valve is not open. If the pressure is very low, it might indicate the pump is not running.

Bit 2: Valve Temperature

If the remainder of **diag_cpec** (after subtracting the numeric value for higher bits that are set) is greater than 1, this means that bit 2 of **diag_cpec** is set. To decode other diagnostic bits, subtract 2 from **diag_cpec** and compare the remainder to the bit values below.

Bit 2 of **diag_cpec** indicates the valve module temperature is outside its operating range. This check is performed only if the CPEC200 program is configured to use a valve module, in which case the check is performed continuously and Boolean variable **valve_tmprOK** is set accordingly. However, the valve module temperature is ignored in EC mode (bit 2 of **diag_cpec** is set only if it is relevant). If the valve module is outside its operating range the zero/span sequence cannot be run, and the valves cannot be selected manually. This protects the valves from possible damage.

To confirm the problem, verify that public variable **valve_tmprOK = False**. This variable is set to **True** if the valve module temperature is within its operating range (0 to 60 °C) and is set to **False** if it is outside this range.

The variable **valve_tmprOK** is not available for diagnosing a problem using data saved in the output tables (**Flux** or **Zero_Span)**. Instead, check the value of **ValveTmprOK_Avg**. This is a floating point number that represents the fraction of time (from 0 to 1) that **valve_tmprOK** is true during the averaging period. A value of 1 indicates no problem with the valve-module temperature at any time during the averaging period. A value of 0 indicates a valve module temperature problem during the entire time.

To continue troubleshooting a problem with the valve module temperature, check the measured temperature, **valve_tmpr**. If it is **NAN**, this indicates a problem with the temperature measurement. Make sure the valve module cable is connected to the side of the valve module.

Next, compare **valve_tmpr** to the operating range (0 to 60 °C). The valve module will be disabled if it is too cold. The valve module has a heater that turns on if **valve_tmpr** falls below 2 °C. If the valve module temperature is too low, check the operation of the heater which is controlled by public variable **valve_heat_ON**. For diagnosing a problem using data saved in the

output table **ts_data**, the state of fans and heaters is encoded into variable **ControlBits** to conserve memory space. See Appendix D, *Control Bits*. This value is saved only if saving all diagnostics. Its corresponding variable **valve_heat_Avg** is saved in the averaged output tables (**Flux** and **Zero_Span**). If the heater is on and the valve module is too cold, check the ambient temperature. The CPEC200 is rated for temperatures from –30 to 50 °C. If the system is started in cold weather after being turned off for several hours, it may take up to 15 minutes to warm up to operating temperature.

The valve module will also be disabled if it is too warm (above 60 °C). The valve module has a fan that turns on if **valve_tmpr** rises above 50 °C. The fan will stay on until the valve temperature falls below 48 °C. If the valve module temperature is too high, check the operation of the fan which is controlled by public variable **valve_fan_ON**. For diagnosing a problem using data saved in the output table **ts_data**, the state of fans and heaters is encoded into variable **ControlBits** to conserve memory space. See Appendix D, *Control Bits*. This value is saved only if saving all diagnostics. Its corresponding variable, **valve_fan_Avg,** is saved in the averaged output tables (**Flux** and **Zero_Span**).

If the fan is on and the valve module temperature is too high, check the ambient temperature. The CPEC200 is rated for ambient temperatures between –30 to 50 °C.

Bit 1: Scrub Module Temperature

If the remainder of **diag_cpec** (after subtracting the numeric value for higher bits that are set) is equal to one, this means that bit 1 of **diag_cpec** is set.

Bit 1 of **diag_cpec** indicates the scrub module temperature is outside its operating range. This check is performed only if the CPEC200 program is configured to use a scrub module. In that case, this check is performed all the time, and Boolean variable, **scrub_tmprOK,** is set accordingly. However, the scrub module temperature is ignored in EC mode (bit 1 of **diag_cpec** is set only if it is relevant). If the scrub module is within its operating range the scrub module pump is turned on any time the **Zero Air** valve is selected. If the scrub module is outside its operating range the zero/span sequence cannot be run, and the **Zero Air** valve (1) cannot be selected manually. This protects the scrub module pump from possible damage.

To confirm the problem, verify that public variable **scrub_tmprOK = False**. This variable is set to **True** if the scrub module temperature is within its operating range (5 to 50 °C) and is set to **False** if it is outside this range.

The variable **scrub_tmprOK** is not available for diagnosing a problem using data saved in the output tables (**Flux** or **Zero_Span)**. Instead, check the value of **ScrubTmprOK_Avg**. This is a floating point number that represents the fraction of time (from 0 to 1) that **scrub_tmprOK** is true during the averaging period. A value of 1 indicates no scrub module temperature problem at any time during the averaging period. A value of 0 indicates a scrub module temperature problem during the entire time.

To continue troubleshooting a problem with the scrub module temperature, check the measured temperature, **scrub_tmpr**. If it is **NAN**, this indicates a problem with the temperature measurement. Make sure the scrub module cable is connected to the **Scrub Module** connector on the bottom of the CPEC200 system enclosure.

Next, compare **scrub_tmpr** it to the operating range (5 to 50 °C). The scrub module will be disabled if it is too cold. The scrub module has a heater that turns on if **scrub_tmpr** falls below 7 °C. If the scrub module temperature is too low, check the operation of the heater which is controlled by public variable **scrub_heat_ON**. For diagnosing a problem using data saved in the output table **ts_data**, the state of fans and heaters is encoded into variable **ControlBits** to conserve memory space. See Appendix D, *Control Bits*. This value is saved only if saving all diagnostics. Its corresponding variable **scrub_heat_Avg** is saved in the averaged output tables (**Flux** and **Zero_Span**). If the heater is on and the scrub module is too cold, check the ambient temperature. The CPEC200 is rated for temperatures from −30 to 50 °C. If the system is started in cold weather after being turned off for several hours, it may take up to 20 minutes to warm up to operating temperature.

The scrub module will also be disabled if it is too warm (above 50 °C). The scrub module has a fan that turns on if **scrub_tmpr** rises above 45 °C. The fan will stay on until the scrub temperature falls below 40 °C. If the scrub module temperature is too high, check the operation of the fan which is controlled by public variable **scrub_fan_ON**. For diagnosing a problem using data saved in the output table **ts_data**, the state of fans and heaters is encoded into variable **ControlBits** to conserve memory space. See Appendix D, *Control Bits*. This value is saved only if saving all diagnostics. Its corresponding variable, **scrub_fan_Avg,** is saved in the averaged output tables (**Flux** and **Zero_Span**).

If the fan is on and the scrub module temperature is too high, check the ambient temperature. The CPEC200 is rated for ambient temperatures between –30 to 50 °C.

Appendix B. Public Variables

Some of the variables in the CPEC200's CRBasic program are included in the **Public** table. These public variables may be displayed or edited with a keyboard display or PC. Other program variables are hidden from the user to reduce clutter in the **Public** table. Many of these public variables are saved in the output tables. Some of the public variables allow the user to set the operation of the system or to give diagnostic information. The intended usage of the public variables is categorized as follows:

IRGA measured by the EC155 gas analyzer
SONIC measured by the CSAT3A sonic anemometer
DIAG diagnostic
USER user setting
INFO provides information on system status
INFO/USER conditional user setting (may set if the sequence is stopped)
CONFIG system configuration parameter - saved in file **sys_conf_var.dat.**

Most of the public variables are defined all the time, but some are dependent on compile constants. The public variables are listed in TABLE B-1.

TABLE B-1. CPEC200 public variables

When Defined	Usage	Variable Name	Units	Description
always		TIMESTAMP	TS	Date and time the record was measured
always		RECORD	RN	Record number
always	DIAG	latest_note		Latest note written to the **message_log** table
always	DIAG	mode_status		Operating state of the CPEC200
always	DIAG	cpec_status		Overall status of the CPEC200
always	DIAG	irga_status		Status of the EC155
always	DIAG	sonic_status		Status of the CSAT3A
always	DIAG	pump_status		Status of the sample pump
always	DIAG	valve_status		Status of the valve module
always	DIAG	EC_mode		Boolean flag: True if the pump is on and no zero/span sequence is running
always	DIAG	diag_cpec		CPEC200 diagnostic word
always	DIAG	irga_OK		Boolean flag: True if no problems are detected with the EC155
always	DIAG	sonic_OK		Boolean flag: True if no problems are detected with the CSAT3A
always	DIAG	pump_flow_OK		Boolean flag: True if the pump flow is within its normal range
always	SONIC	Ux	$m \cdot s^{-1}$	Wind velocity X component
always	SONIC	Uy	$m \cdot s^{-1}$	Wind velocity Y component
always	SONIC	Uz	$m \cdot s^{-1}$	Wind velocity Z component
always	SONIC	Ts	ºC	Sonic virtual temperature

TABLE B-1. CPEC200 public variables

When Defined	Usage	Variable Name	Units	Description
always	SONIC	diag_sonic		CSAT3A diagnostic word
always	IRGA	CO2	$\mu mol \cdot mol^{-1}$	CO_2 mixing ratio, relative to dry air
always	IRGA	H2O	$\mu mol \cdot mol^{-1}$	H_2O vapor mixing ratio, relative to dry air
always	IRGA	diag_irga		EC155 diagnostic word
always	IRGA	cell_tmpr	ºC	Temperature of the sample cell
always	IRGA	cell_press	kPa	pressure in the sample cell
always	IRGA	CO2_signal		Relative strength of the infrared signal in the CO_2 absorption band
always	IRGA	H2O_signal		Relative strength of the infrared signal in the H_2O absorption band
always	IRGA	diff_press	kPa	Differential pressure (sample cell, relative to ambient)
always	IRGA	source_tmpr	ºC	Temperature measured inside the source housing
always	IRGA	not_used		Placeholder variable to receive a value from the EC100 (used for an EC150, but not used for an EC155)
always	INFO	Td_cell	ºC	H_2O converted to dewpoint temperature in the sample cell
always	INFO	Td_ambient	ºC	Dewpoint temperature corrected for pressure difference between the sample cell and ambient
always	USER	pump_ON		set = True to enable the sample pump
always	INFO	pump_flow	LPM	sample pump speed, converted to volumetric flow rate
always	INFO	pump_control		pump speed control variable; can be from 0 (off) to 1 (full speed)
always	INFO	pump_press	kPa	pressure measured at the sample pump inlet
always	INFO	pump_tmpr	ºC	temperature of the pump
always	DIAG	pump_tmpr_OK		Boolean flag: True if the pump temperature is within its operating range
always	INFO	pump_heat_ON		Boolean flag: True if the pump heater is on
always	INFO	pump_fan_ON		Boolean flag: True if the pump fan is on
VALVE_MODULE	USER	STARTsequence		Set = True to manually initiate a zero/span sequence
VALVE_MODULE	INFO/USER	valve_number		Valve number (0 to 6); determines which zero/span valve is selected

TABLE B-1. CPEC200 public variables

When Defined	Usage	Variable Name	Units	Description
VALVE_MODULE	USER	DO_P_offset		Set = True to measure the pressure offset
VALVE_MODULE	INFO	press_offset	kPa	Sample cell pressure measured with no flow; used to infer valve flow
VALVE_MODULE	INFO/USER	valveTctl_ON		Set = True to enable valve module temperature control
VALVE_MODULE	INFO	valve_tmpr	ºC	Temperature of the valve module
VALVE_MODULE	DIAG	valve_tmprOK		Boolean flag: True if the valve temperature is within its operating range
VALVE_MODULE	INFO	valveHeat_ON		Boolean flag: True if the valve heater is on
VALVE_MODULE	INFO	valveFan_ON		Boolean flag: True if the valve fan is on
VALVE_MODULE	INFO	valve_flow	LPM	Zero/span flow
VALVE_MODULE	DIAG	valve_flow_OK		Boolean flag: True if valve_flow is within the normal range
VALVE_MODULE	INFO	valveControl		Zero/span flow control valve; can be from 0 (closed) to 1 (open)
SCRUB_MODULE	INFO	scrub_tmpr	ºC	Temperature of the scrub module
SCRUB_MODULE	DIAG	scrub_tmprOK		Boolean flag: True if the scrub module temperature is within its operating range
SCRUB_MODULE	INFO	scrubHeat_ON		Boolean flag: True if the scrub module heater is on
SCRUB_MODULE	INFO	scrubFan_ON		Boolean flag: True if the scrub module fan is on
SCRUB_MODULE	INFO	scrub_press	kPa	Pressure measured at the scrub pump outlet
VALVE_MODULE	INFO/USER	DO_zero		Set = True to send the CO_2 and H_2O zero command to the IRGA
VALVE_MODULE	INFO/USER	DO_CO2_span		Set = True to send the CO_2 span command to the IRGA
VALVE_MODULE	USER	H2OSpanDewPt	ºC	Setpoint temperature on dewpoint generator; used for H_2O span
VALVE_MODULE	USER	DO_H2O_span		Set = True to send the H_2O span command to the IRGA
always	INFO	BattVolt	V	Supply voltage; measured inside datalogger after diode voltage drop
always	DIAG	BattVolt_OK		Boolean flag: False if the CPEC200 system has shut down because the supply voltage was too low

TABLE B-1. CPEC200 public variables

When Defined	Usage	Variable Name	Units	Description
always	INFO	panel_tmpr	ºC	Temperature of the datalogger wiring panel
always	INFO	process_time	µs	Time to process the scan (a copy of ProcessTime from the Status table)
always	INFO	buff_depth		Number of scans in the pipeline buffer that have not yet been processed (a copy of BuffDepth from the Status table)
always	DIAG	buff_depth_OK		Boolean flag: False if buff_depth exceeds the limit (disables pump speed and valve flow controls)
always	INFO	intake_heater	V	Voltage applied to the EC155 intake heater
Leaf_Wetness_Sensor	INFO	leaf_wetness		Measurement from an optional leaf wetness sensor (used to control intake heater voltage)
always	CONFIG	BATT_LOWLIMIT	V	CPEC200 will power down if supply voltage falls below this limit
always	CONFIG	BATT_DEADBAND	V	CPEC200 will power up if supply voltage rises this much above the lower limit
always	CONFIG	SONIC_AZIMUTH	degrees	Angle between true north and the direction the CSAT3A is pointing
always	CONFIG	BANDWIDTH	Hz	EC100 digital filter bandwidth
always	CONFIG	AMB_PRESS_NOMINAL	kPa	nominal ambient pressure for CPEC200 elevation
always	CONFIG	PUMP_SETPT	LPM	Flow setpoint for sample pump speed control
always	CONFIG	CAL_INTERVAL	min	Time between automatic zero/span sequences
always	CONFIG	CAL_TIMEOFFSET	min	Time offset for starting automatic zero/span sequences
always	CONFIG	ZERO_TIME	s	Time to flow zero gas
always	CONFIG	SPAN_TIME	s	Time to flow CO_2 span gas
always	CONFIG	CAL_FLOW_SETPT	LPM	Flow setpoint for zero/span
always	CONFIG	CO2_SPAN_PPM	$\mu mol \cdot mol^{-1}$	CO_2 mixing ratio in the CO_2 span cylinder
always	CONFIG	USE_DIFF_PRESS		Set = True to enable the EC155 differential pressure sensor
always	CONFIG	CHECK_ZERO		Set = True to enable automatic zero/span sequences
always	CONFIG	SET_ZERO		Set = True to set the zero during automatic zero/span sequences
always	CONFIG	CHECK_SPAN1		Set = True to check the CO_2 span during automatic zero/span sequences

TABLE B-1. CPEC200 public variables				
When Defined	**Usage**	**Variable Name**	**Units**	**Description**
always	CONFIG	SET_SPAN_1		Set = True to set the CO_2 span during automatic zero/span sequences
always	CONFIG	CHECK_SPAN2		Set = True to measure CO_2 span cylinder 2 during automatic zero/span sequences
always	CONFIG	CHECK_SPAN3		Set = True to measure CO_2 span cylinder 3 during automatic zero/span sequences
always	CONFIG	CHECK_SPAN4		Set = True to measure CO_2 span cylinder 4 during automatic zero/span sequences

Appendix C. Output Variables

The CPEC200 program stores data in several output tables. Details are given for each table.

ts_data

The primary output table is **ts_data** table which gives time-series data. This table stores each sample of the raw CPEC200 data (ten records per sec). The CPEC200 program stores this table in multiple files on the memory card, with a new file started each day at midnight. The size of these daily files depends on the compile flags. With the default settings, each file is approximately 62 kB and a 2 GB memory card will store data for approximately four weeks before the CPEC200 program begins to delete old files to make room for new files. If no valve module is used, the time-series files are slightly smaller, approximately 55 kB. The largest files will occur when the compile switch is set to store all diagnostic information, and use the valve module and scrub modules. These daily files are approximately 120 kB in size. See Section 5.4.2, *Compile Switches*, for details on setting program constants. If more storage is required, a 16 GB memory card, the CFMC16G, is available.

The values stored in table **ts_data** are shown in TABLE C-1. Values that are stored or not stored depending on compile switch settings have a V, D or S in the first column of TABLE C-1.

- V means the value is stored only if **VALVE_MODULE** = **True**
- D means the value is stored only if **SaveAll_diagnostics** = **True**
- S means the value is stored only if **SCRUB_MODULE** = **True**

If multiple compile switches are listed for a value, the value is stored in the table only if all of the compile switches are **True**. If no compile switches are listed for a value, the value is always stored in the table.

TABLE C-1. Values stored in table ts_data

Compile Switch	Variable Name	Units	Description
	TIMESTAMP	TS	Date and time the record was measured
	RECORD	RN	Record number
	EC_mode		Boolean flag: True if the pump is on and no zero/span sequence is running
	diag_cpec		CPEC200 diagnostic word
	Ux	$m \cdot s^{-1}$	Wind velocity X component
	Uy	$m \cdot s^{-1}$	Wind velocity Y component
	Uz	$m \cdot s^{-1}$	Wind velocity Z component
	Ts	ºC	Sonic virtual temperature
	diag_sonic		CSAT3A diagnostic word
	CO2	$\mu mol \cdot mol^{-1}$	CO_2 mixing ratio, relative to dry air
	H2O	$mmol \cdot mol^{-1}$	H_2O vapor mixing ratio, relative to dry air
	diag_irga		EC155 diagnostic word
	cell_tmpr	ºC	Temperature of the sample cell

TABLE C-1. Values stored in table ts_data

Compile Switch	Variable Name	Units	Description
	cell_press	kPa	Pressure in the sample cell
	diff_press	kPa	Differential pressure (sample cell, relative to ambient)
	pump_flow	LPM	Sample pump speed, converted to volumetric flow rate
V	valve_number		Valve number (0 to 6); determines which zero/span valve is selected
V	valve_flow	LPM	zero/span flow
D	CO2_signal		Relative strength of the infrared signal in the CO_2 absorption band
D	H2O_signal		Relative strength of the infrared signal in the H_2O absorption band
D	source_tmpr	ºC	Temperature measured inside the source housing
D	pump_control		Pump speed control variable; can be from 0 (off) to 1 (full speed)
D	pump_press	kPa	Pressure measured at the sample pump inlet
D	pump_tmpr	ºC	Temperature of the pump
D	ControlBits		Status of heaters and fans (see Appendix D, *Control Bits*, for details)
D, V	SequenceStep		Status of the zero/span sequence (see TABLE 6-1 for details)
D, V	valve_tmpr	ºC	Temperature of the valve module
D, V	valveControl		Zero/span flow control valve; can be from 0 (closed) to 1 (open)
D, V, S	scrub_press	kPa	Pressure measured at the scrub pump outlet
D, V, S	scrub_tmpr	ºC	Temperature of the scrub module
D	BattVolt	V	Supply voltage; measured inside datalogger after diode voltage drop
D	process_time	µs	Time to process the scan (a copy of ProcessTime from the Status table)
D	buff_depth		Number of scans in the pipeline buffer that have not yet been processed (a copy of BuffDepth from the Status table)

flux

The online flux calculations are stored in table **flux**. A record is written to this table at the end of every output interval (30 min). Space is allocated on the memory card for 9,600 records (200 days at one record per 30 min). The CPU has storage allocated for 480 records (10 days).

Most of the values stored in table **flux** are always stored, but some are dependent on the settings for program constants. See Section 5.4.2, *Compile Switches*, for details on setting program constants.

The first six values (**Hs** through **u_star**) are the basic online flux calculations.

The next five values (**Ux_Lag_Avg** through **sonic_samples**) are averages of the sonic anemometer outputs. These are averages of the values that have been lagged to align the sonic and IRGA data. They are filtered to include only those data for which there are no sonic diagnostic flags.

The next six values (**CO2_Lag_Avg** through **irga_samples**) are the corresponding lagged averages of the EC155 data.

The next two values (**pump_flow_Lag_avg** and **pump_OK_samples**) are the corresponding lagged averages for the pump flow.

The next eleven values (**wind_speed** through **flux samples**) give several values associated with the online fluxes. The number of samples included in these calculations (**flux_samples**) includes only those samples for which all of the data (sonic, irga, and pump) are OK.

The next twenty-two values (**Ts_stdev** through **Tc_Uz_cov**) are the covariance matrices of the various flux components.

The next nineteen values (**Ux_Avg** through **diag_CPEC_Avg**) are averages of the corresponding public variables. Many of these values are similar to lagged values that are also found in this table, for example **Ux_Lag_Avg** and **Ux_Avg**. These differ in two ways. First, the lagged versions represent an average of a slightly different time period (up to two seconds earlier, corresponding to the actual online flux calculations). Second, the lagged versions are filtered to exclude values for which a diagnostic flag was set. The non-lagged versions are simply the averages of all of the measurements within the output interval. The rest of the values provide diagnostic information about the CPEC200 system.

The value of the compile switches as shown in TABLE C-2 depends on the constants as described in Section 5.4.2, *Compile Switches.* The code shown in the table can be either V, S, or LWS, or a combination of two of the codes.

- V is defined if **VALVE_MODULE** = **True**
- S is defined if **SCRUB_MODULE** = **True** and **VALVE_MODULE** = **True**
- LWS is defined if **Leaf_Wetness_Sensor = True**

TABLE C-2. Values stored in table flux

Compile Switch	Variable Name	Units	Description
	TIMESTAMP	TS	Date and time the record was measured
	RECORD	RN	Record number
	Hs	$W \cdot m^{-2}$	Sensible heat flux from sonic temperature Ts
	Hc	$W \cdot m^{-2}$	Sensible heat flux from corrected sonic temperature Tc
	LE	$W \cdot m^{-2}$	Latent heat flux
	Fc	$mg \cdot m^{-2} \cdot s^{-1}$	CO_2 flux
	tau	$kg \cdot m^{-1} \cdot s^{-2}$	Momentum flux
	u_star	$m \cdot s^{-1}$	Friction velocity
	Ux_Lag_Avg	$m \cdot s^{-1}$	Average of (lagged) U_x
	Uy_Lag_Avg	$m \cdot s^{-1}$	Average of (lagged) U_y
	Uz_Lag_Avg	$m \cdot s^{-1}$	Average of (lagged) U_z
	Ts_Lag_Avg	ºC	Average of (lagged) T_s
	sonic_samples		Number of samples included in previous 5 averages
	CO2_Lag_Avg	$\mu mol \cdot mol^{-1}$	Average of (lagged) CO_2
	H2O_Lag_Avg	$mmol \cdot mol^{-1}$	Average of (lagged) H_2O
	cell_tmpr_Lag_Avg	ºC	Average of (lagged) cell temperature
	cell_press_Lag_Avg	kPa	Average of (lagged) cell pressure
	diff_press_Lag_Avg	kPa	Average of (lagged) differential pressure
	irga_samples		Number of samples included in previous 5 averages
	pump_flow_Lag_Avg	LPM	Average of (lagged) pump flow
	pump_OK_samples		Number of samples included in previous average

TABLE C-2. Values stored in table flux

Compile Switch	Variable Name	Units	Description
	wind_speed	$m \cdot s^{-1}$	Average wind speed
	wind_vector_mag	$m \cdot s^{-1}$	Magnitude of average wind vector
	wind_dir_sonic	degrees	direction of average wind vector
	stdev_wind_dir	degrees	Standard deviation of wind direction
	wind_dir_compass	degrees	Wind direction in compass coordinates
	Tc_mean	ºC	Average of the humidity-corrected sonic temperature
	amb_press_mean	kPa	Average ambient pressure
	rho_a_mean	$kg \cdot m^{-3}$	Average density of humid air
	Td_cell_mean	ºC	Average dewpoint temperature in the sample cell
	Td_ambient_mean	ºC	Average dewpoint temperature at ambient pressure
	flux_samples		Number of samples included in flux calculations
	Ts_stdev	ºC	Standard deviation of sonic temperature Ts
	Ts_Ux_cov	ºC $m \cdot s^{-1}$	Covariance of T_s and U_x
	Ts_Uy_cov	ºC $m \cdot s^{-1}$	Covariance of T_s and U_y
	Ts_Uz_cov	ºC $m \cdot s^{-1}$	Covariance of T_s and U_z
	Ux_stdev	$m \cdot s^{-1}$	Standard deviation of U_x
	Ux_Uy_cov	$m^2 \cdot s^{-2}$	Covariance of U_x and U_y
	Ux_Uz_cov	$m^2 \cdot s^{-2}$	Covariance of U_x and U_z
	Uy_stdev	$m \cdot s^{-1}$	Standard deviation of U_y
	Uy_Uz_cov	$m^2 \cdot s^{-2}$	Covariance of U_y and U_z
	Uz_stdev	$m \cdot s^{-1}$	Standard deviation of U_z
	CO2_stdev	$\mu mol\ mol^{-1}$	Standard deviation of CO_2
	CO2_Ux_cov	$\mu mol \cdot mol^{-1}\ m \cdot s^{-1}$	Covariance of CO_2 and U_x
	CO2_Uy_cov	$\mu mol \cdot mol^{-1}\ m \cdot s^{-1}$	Covariance of CO_2 and U_y
	CO2_Uz_cov	$\mu mol \cdot mol^{-1}\ m \cdot s^{-1}$	Covariance of CO_2 and U_z
	H2O_stdev	$mmol \cdot mol^{-1}$	Standard deviation of H_2O
	H2O_Ux_cov	$mmol \cdot mol^{-1}\ m \cdot s^{-1}$	Covariance of H_2O and U_x
	H2O_Uy_cov	$mmol \cdot mol^{-1}\ m \cdot s^{-1}$	Covariance of H_2O and U_y
	H2O_Uz_cov	$mmol \cdot mol^{-1}\ m \cdot s^{-1}$	Covariance of H_2O and U_z
	Tc_stdev	ºC	Standard deviation of humidity-corrected sonic temperature T_c
	Tc_Ux_cov	°C $m \cdot s^{-1}$	Covariance of T_c and U_x
	Tc_Uy_cov	°C $m \cdot s^{-1}$	Covariance of T_c and U_y
	Tc_Uz_cov	°C $m \cdot s^{-1}$	Covariance of T_c and U_z
	Ux_Avg	$m \cdot s^{-1}$	Average of U_x
	Uy_Avg	$m \cdot s^{-1}$	Average of U_y
	Uz_Avg	$m \cdot s^{-1}$	Average of U_z
	Ts_Avg	ºC	Average of T_s
	diag_sonic_Avg		Average of diag_sonic
	CO2_Avg	$\mu mol \cdot mol^{-1}$	Average of CO_2
	H2O_Avg	$mmol \cdot mol^{-1}$	Average of H_2O
	diag_irga_Avg		Average of diag_irga
	cell_tmpr_Avg	ºC	Average cell temperature
	cell_press_Avg	kPa	Average cell pressure
	CO2_signal_Avg		Average CO_2 signal
	H2O_signal_Avg		Average H_2O signal
	diff_press_Avg	kPa	Average differential pressure

TABLE C-2. Values stored in table flux

Compile Switch	Variable Name	Units	Description
	source_tmpr_Avg	ºC	Average source temperature
	pump_ON_Avg		Fraction of time the pump was on
	pump_flow_Avg	LPM	Average pump flow
	pump_control_Avg		Average pump control value
	pump_press_Avg	kPa	Average pump pressure
	diag_CPEC_Avg		Average of diag_cpec
	fast_samples		Number of samples included in the averages for values measured in the main scan
	buff_depth_Max		Maximum buffer depth during the output interval
	process_time_Avg	µsec	Average processing time
	PumpTmprOK_Avg		Fraction of time the pump temperature was within its operating range
	pump_tmpr_Avg	ºC	Average pump temperature
	pump_heat_Avg		Fraction of time the pump heater was on
	pump_fan_Avg		Fraction of time the pump fan was on
	panel_tmpr_Avg	ºC	Average datalogger wiring panel temperature
	BattVolt_Avg	V	Average supply voltage
	BattVoltOK_Avg		Fraction of time the system was not shut down because the supply temperature had dropped below the limit
	slow_samples		Number of samples included in the average for values Measured in the slow scan
V	ValveTmprOK_Avg		Fraction of time the valve module temperature was within its operating range
V	valve_tmpr_Avg	ºC	Average valve module temperature
V	valve_heat_Avg		Fraction of time the valve module heater was on
V	valve_fan_Avg		Fraction of time the valve module fan was on
V, S	scrub_press_Avg	kPa	average pressure at the scrub pump outlet
V, S	ScrubTmprOK_Avg		Fraction of time the scrub module temperature was within its operating range
V, S	scrub_tmpr_Avg	ºC	Average scrub module temperature
V, S	scrub_heat_Avg		Fraction of time the scrub module heater was on
V, S	scrub_fan_Avg		Fraction of time the scrub module fan was on
LWS	leaf_wetness_Avg		Average leaf wetness sensor reading
LWS	intake_heater_Avg	V	Average intake heater voltage

zero_span

The **zero_span** table contains data from the automated zero/span sequences. Records are written to this table when the calibration sequence is run (either automatically initiated based on time, or manually initiated). Each zero/span sequence will put multiple records in the **zero_span** table, corresponding to the steps in the sequence. The actual number of records will depend on which options are chosen. If a step is skipped, no record will be written to table for that step. See Section 6.2, *Automatic Zero and Span*, for details.

The records in the **zero_span** table are distinguished by the first two values: Sequence_Step (1 to 11) and V**alveNumber** (0 if no valve is selected, or 1 to 6). Space is allocated on the card for 33,000 records (approximately 200 days

at seven records per sequence, and sequences run every hour). The CPU has storage allocated for 500 records (3 days).

The **zero_span** table is defined only if **VALVE_MODULE** = **True**. As a result, only the last five values, associated with the scrub module, are optional depending on the **SCRUB_MODULE** compile switch.

The value of the compile switches as shown in TABLE C-3 depends on the constants as described in Section 5.4.2, *Compile Switches.* The code shown in the table can be either V, S, or a combination of two of the codes.

- V is defined if **VALVE_MODULE** = **True**
- S is defined if **SCRUB_MODULE** = **True** and **VALVE_MODULE** = **True**

TABLE C-3. Values stored in table zero_ span

Compile Switch	Variable Name	Units	Description
V	TIMESTAMP	TS	Date and time the record was measured
V	RECORD	RN	Record number
V	Sequence_Step		Status of the zero/span sequence (see Section 6.2, *Automatic Zero and Span*, for details)
V	ValveNumber		Valve number (0 to 6); determines which zero/span valve is selected
V	CO2_Avg	$\mu mol \cdot mol^{-1}$	Average of CO_2
V	H2O_Avg	$mmol \cdot mol^{-1}$	Average of H_2O
V	diag_irga_Avg		Average of diag_irga
V	cell_tmpr_Avg	ºC	Average cell temperature
V	cell_press_Avg	kPa	Average cell pressure
V	CO2_signal_Avg		Average CO_2 signal
V	H2O_signal_Avg		Average H_2O signal
V	diff_press_Avg	kPa	Average differential pressure
V	source_tmpr_Avg	ºC	Average source temperature
V	pump_ON_Avg		Fraction of time the pump was on
V	pump_flow_Avg	LPM	Average pump flow
V	pump_control_Avg		Average pump control value
V	pump_press_Avg	kPa	Average pump pressure
V	diag_CPEC_Avg		Average of diag_cpec
V	fast_samples		Number of samples included in the averages for values measured in the main scan
V	buff_depth_Max		Maximum buffer depth during the output interval
V	process_time_Avg	µsec	Average processing time
V	PressOffset	kPa	Sample cell pressure measured with no flow; used to infer valve flow
V	valve_flow_Avg	LPM	Average zero/span flow
V	valveControl_Avg		Average of zero/span flow control valve; can be from 0 (closed) to 1 (open)
V	PumpTmprOK_Avg		Fraction of time the pump temperature was within its operating range
V	pump_tmpr_Avg	ºC	Average pump temperature
V	pump_heat_Avg		Fraction of time the pump heater was on
V	pump_fan_Avg		Fraction of time the pump fan was on

TABLE C-3. Values stored in table zero_ span			
Compile Switch	**Variable Name**	**Units**	**Description**
V	panel_tmpr_Avg	ºC	Average datalogger wiring panel temperature
V	BattVolt_Avg	V	Average supply voltage
V	BattVoltOK_Avg		Fraction of time the system was not shut down because the supply temperature had dropped below the limit
V	slow_samples		Number of samples included in the average for values measured in the slow scan
V	ValveTmprOK_Avg		Fraction of time the valve module temperature was within its operating range
V	valve_tmpr_Avg	ºC	Average valve module temperature
V	valve_heat_Avg		Fraction of time the valve module heater was on
V	valve_fan_Avg		Fraction of time the valve module fan was on
V, S	scrub_press_Avg	kPa	Average pressure at the scrub pump outlet
V, S	ScrubTmprOK_Avg		Fraction of time the scrub module temperature was within its operating range
V, S	scrub_tmpr_Avg	ºC	Average scrub module temperature
V, S	scrub_heat_Avg		Fraction of time the scrub module heater was on
V, S	scrub_fan_Avg		Fraction of time the scrub module fan was on

message_log

The **message_log** table stores a record that includes a text message as well as several variables that describe the state of the system when the record is written. It notifies the user of a significant event, such as a change to a configuration variable or events related to a zero/span sequence.

Public variable **latest_note** shows the latest message written to the **message_log** table. After one minute the text in **latest_note** is marked as old, but is still displayed.

Some of the messages relate to the system configuration variables. The first message, written when the program starts up, will be either:

- *Using configuration variables from sys_conf_var.dat*

or:

- *Using default configuration variables*

This is normally followed by:

- *System configuration saved*

This message is also written any time the configuration is saved: once per day at 15 minutes past midnight and any time a configuration variable is changed.

Most of the messages are related to the Zero/Span sequence. When the sequence starts and stops normally, the following messages are displayed.

- *Zero/Span sequence started*
- *Zero/Span sequence completed*

If there is some error condition that prevents the zero/span sequence from starting, one of the following messages will be displayed:

- *ERROR: Cannot run Zero/Span sequence - CHECK_ZERO is False*
- *ERROR: Cannot run Zero/Span sequence - Check valve temperature*
- *ERROR: Cannot run Zero/Span - Check scrub module temperature*

If the CPEC200 begins the startup process for a zero/span sequence, and then detects an error, one of the following messages will be displayed:

- *Zero/Span startup manually aborted by turning pump on*
- *ERROR: Zero/Span startup aborted - Check scrub module temperature*
- *ERROR: Zero/Span startup aborted - Check valve temperature*

If the CPEC200 has already started the zero/span sequence and then detects some error condition that causes the zero/span sequence to abort, one of the following messages will be displayed:

- *Zero/Span sequence manually aborted by turning pump on*
- *ERROR: Zero/Span sequence aborted - Check scrub module temperature*
- *ERROR: Zero/Span sequence aborted - Check valve temperature*

If the CPEC200 attempts to set the IRGA zero or span as part of a zero/span sequence and there is a problem identified (**diag_cpec** is nonzero), the CPEC200 will skip the zero or span setting step, continue the rest of the sequence, and display one of the following messages. If the user attempts to set the zero or span manually this error or check is bypassed, and the zero or span will be set regardless of the status of **diag_cpec**.

- *ERROR: Automatic Zero aborted - Check diagnostics*
- *ERROR: Automatic CO2 Span aborted - Check diagnostics*

Some of the messages relate to the use of the valve module in manual mode:

- *Valve operation not allowed when pump is on*
- *EC mode restarted by turning pump on*
- *ERROR: Valves disabled - Check valve temperature*
- *ERROR: Valves disabled - Check press_offset*
- *ERROR: Valves disabled - Check scrub module temperature*

Some of the messages relate to the configuration of the EC155:

- *ERROR: Powering OFF EC155 gas head*
- *Powering ON EC155 gas head*
- *Configuring the EC100*
- *Setting the zero*
- *Setting the CO2 span*
- *Setting the H2O span*

The values stored in table **message_log** are shown in TABLE C-4. The value of the compile switches depends on the constants as described in Section 5.4.2,

Compile Switches. The code shown in the table can be either V, S, or a combination of two of the codes.

- V is defined if **VALVE_MODULE** = **True**
- S is defined if **SCRUB_MODULE** = **True** and **VALVE_MODULE** = **True**

TABLE C-4. Values stored in table message_log

Compile Switch	Variable Name	Units	Description
	TIMESTAMP	TS	Date and time the record was written
	RECORD	RN	Record number
	message_str		Message explaining why the record was written
	mode_status		Operating state of the CPEC200
	cpec_status		Overall status of the CPEC200
	sonic_status		Status of the CSAT3A
	irga_status		Status of the EC155
	pump_status		Status of the sample pump
	valve_status		Status of the valve module
	panel_tmpr	ºC	Temperature of the datalogger wiring panel
	BattVolt	V	Supply voltage; measured inside datalogger after diode voltage drop
	Ts	ºC	Sonic virtual temperature
	CO2	$\mu mol \cdot mol^{-1}$	CO_2 mixing ratio, relative to dry air
	H2O	$mmol \cdot mol^{-1}$	H_2O vapor mixing ratio, relative to dry air
	CO2_signal		Relative strength of the infrared signal in the CO_2 absorption band
	H2O_signal		relative strength of the infrared signal in the H_2O absorption band
	diff_press	kPa	differential pressure (sample cell, relative to ambient)
	source_tmpr	ºC	temperature measured inside the source housing
	pump_ON		Boolean flag: True if sample pump is on
	pump_flow	LPM	Sample pump speed, converted to volumetric flow rate
	pump_tmpr	ºC	Temperature of the pump
	pump_press	kPa	Pressure measured at the sample pump inlet
V	SequenceStep		Status of the zero/span sequence (see Section 6.2, *Automatic Zero and Span*, for details)
V	smpl_counter		How long (number of scans) the sequence has been at this step

TABLE C-4. Values stored in table message_log			
Compile Switch	**Variable Name**	**Units**	**Description**
V	valve_number		Valve number (0 to 6); determines which zero/span valve is selected
V	press_offset	kPa	Sample cell pressure measured with no flow; used to infer valve flow
V	valveTctl_ON		Boolean flag: True if valve module temperature control is enabled
V	valve_flow	LPM	Zero/span flow
V	valve_tmpr	ºC	Temperature of the valve module
V, S	scrub_tmpr	ºC	Temperature of the scrub module
V, S	scrub_press	kPa	Pressure measured at the scrub pump outlet
	buff_depth		Number of scans in the pipeline buffer that have not yet been processed (a copy of BuffDepth from the Status table)

config_history

The user may change the configuration of the CPEC200 program at any time, as discussed in Section 5.4, *Configure the Program*. All the configuration variables and compile switches are written to the **config_history** table at startup, when a configuration variable is changed, and once a day at 15 minutes past midnight. This provides a historical record to be used as a troubleshooting aid.

The values stored in table **config_history** are shown in TABLE C-5.

TABLE C-5. Values stored in table config_history		
Variable Name	**Units**	**Description**
TIMESTAMP	TS	Date and time the record was written
RECORD	RN	record number
BATT_LOWLIMIT	V	CPEC200 will power down if supply voltage falls below this limit
BATT_DEADBAND	V	CPEC200 will power up if supply voltage rises this much above the lower limit
SONIC_AZIMUTH	degrees	Angle between true north and the direction the CSAT3A is pointing
BANDWIDTH	Hz	EC100 digital filter bandwidth
AMB_PRESS_NOMINAL	kPa	Nominal ambient pressure for CPEC200 elevation
PUMP_SETPT	LPM	Flow setpoint for sample pump speed control
CAL_INTERVAL	min	Time between automatic zero/span sequences
CAL_TIMEOFFSET	min	Time offset for starting automatic zero/span sequences
ZERO_TIME	s	Time to flow zero gas
SPAN_TIME	s	Time to flow CO_2 span gas
CAL_FLOW_SETPT	LPM	Flow setpoint for zero/span

TABLE C-5. Values stored in table config_history

Variable Name	Units	Description
CO2_SPAN_PPM	$\mu mol \cdot mol^{-1}$	CO_2 mixing ratio in the CO_2 span cylinder
USE_DIFF_PRESS		Set = True to enable the EC155 differential pressure sensor
CHECK_ZERO		Set = True to enable automatic zero/span sequences
SET_ZERO		Set = True to set the zero during automatic zero/span sequences
CHECK_SPAN1		Set = True to check the CO_2 span during automatic zero/span sequences
SET_SPAN_1		Set = True to set the CO_2 span during automatic zero/span sequences
CHECK_SPAN2		Set = True to measure CO_2 span cylinder 2 during automatic zero/span sequences
CHECK_SPAN3		Set = True to measure CO_2 span cylinder 3 during automatic zero/span sequences
CHECK_SPAN4		Set = True to measure CO_2 span cylinder 4 during automatic zero/span sequences
VALVE_MODULE		Compile switch: set = True to enable the use of the valve module
SCRUB_MODULE		Compile switch: set = True to enable the use of the scrub module
SaveAll_diagnostics		Compile switch: set = True to save additional diagnostic values in the time series data table
Leaf_Wetness_Sensor		Compile switch: set = True to control intake heater voltage based on a leaf wetness sensor

Appendix D. Control Bits

For diagnosing a problem using data saved in the output table, **ts_data**, the state of fans and heaters is encoded into variable **ControlBits** to conserve memory space. A user unfamiliar with converting a decimal number to binary may find it convenient to use a decimal-to-binary converter that can be found on the Internet. Alternately, follow the step-by-step troubleshooting instructions as a guide through the conversion process.

Note: the CPEC200 controls power to the heaters and fans with a 16-channel control module, the SDM-CD16S. This same module controls the valves and the scrub pump, as noted in the table. The state of the valves and scrub module are set by **valve_number**, and are not reported in **ControlBits**.

TABLE D-1. CPEC200 temperature control bits encoded in ControlBits

Binary Bit (LSB = 1)	Numeric Value	Corresponding public variable (bit is set if variable=True)	Notes
14 - 16			Not used
13	4096	scrubFan_ON	Scrub module fan is on
12	2048	scrubHeat_ON	Scrub module heater is on
11			Used for scrub pump (not included in **ControlBits**)
10	512	pump_fan_ON	Sample pump fan is on
9	256	pump_heat_ON	Sample pump heater is on
8	128	valveFan_ON	Valve module fan is on
7	64	valveHeat_ON	Valve module heater is on
1 – 6			Used to switch valves (not included in **ControlBits**)
none	0		All heaters and fans are off

If **ControlBits** is greater than 4095, this indicates bit 13 of **ControlBits** is set. This means the scrub module fan is on. To decode other temperature control bits, subtract 4096 from **ControlBits** and compare the remainder to the bit values below.

If **ControlBits** is greater than 2047, this indicates bit 12 of **ControlBits** is set. This means the scrub module heater is on. To decode other temperature control bits, subtract 2048 from **ControlBits** and compare the remainder to the bit values below.

If **ControlBits** is greater than 511, this indicates bit 10 of **ControlBits** is set. This means the sample pump fan is on. To decode other temperature control bits, subtract 512 from **ControlBits** and compare the remainder to the bit values below.

If **ControlBits** is greater than 255, this indicates bit 9 of **ControlBits** is set. This means the sample pump heater is on. To decode other temperature control bits, subtract 256 from **ControlBits** and compare the remainder to the bit values below.

If **ControlBits** is greater than 127, this indicates bit 8 of **ControlBits** is set. This means the valve module fan is on. To decode other temperature control bits, subtract 128 from **ControlBits** and compare the remainder to the bit values below.

If **ControlBits** is equal to 64, this indicates bit 7 of **ControlBits** is set. This means the valve module heater is on.

Appendix E. Using Swagelok® Fittings

This appendix gives a few tips on using Swagelok® tube fittings. For more information, consult your local Swagelok® dealer or visit their web site at *www.swagelok.com*.

General Notes:

- Do not use fitting components from other manufacturers – they are not interchangeable with Swagelok® fittings.
- Do not attempt to use metric fittings. Six mm is very close to 1/4 in, but they are not interchangeable. Metric fittings can be identified by the stepped shoulder on the nut and on the body hex.
- Make sure that the tubing rests firmly on the shoulder of the tube fitting body before tightening the nut.
- Never turn the fitting body. Instead, hold the fitting body and turn the nut.
- Keep tubing and fittings clean. Always use caps and plugs to keep dirt and debris out.
- Do not overtighten fittings as it will damage the threads.

If a nut cannot be easily tightened by hand, this indicates the threads have been damaged. Replace any damaged nuts and fittings.

E.1 Assembly

The first time a Swagelok® fitting is assembled, the ferrules become permanently swaged onto the tube. Assembly instructions vary depending on plastic or metal tubing. The assembly instructions are also slightly different for an initial installation than for subsequent reassembly.

First-time assembly, plastic tubing:

1. Cut the tubing to length.
2. Make sure the cut is square and free of burrs.
3. Some types of plastic tubing have an aluminum layer. Take care not to flatten the tube as you cut it.
4. Push an insert into the end of the tubing.
5. Do not remove the nuts and ferrules from the fitting. Simply insert the tube into the assembled fitting until it bottoms out.
6. Rotate the nut finger-tight.
7. While holding the fitting body steady, tighten the nut one and one-quarter turns. (For 1/16 in or 1/8 in-sized fittings, tighten the nut three-quarters turn.)

First-time assembly, metal tubing:
Extra care is needed to avoid overtightening brass fittings when used with metal tubing. These notes apply to reducers and port connectors as well as metal tubing.

NOTE No insert is required with metal tubing.

1. Do not remove the nuts and ferrules from the fitting. Simply insert the tube into the assembled fitting until it bottoms out.
2. Rotate the nut finger tight.
3. While holding the fitting body steady, tighten the nut until it feels tight. This will normally be less than one full turn. Tightening a full one and one-quarter turns will damage the threads on the fitting and nut.

Reassembly, plastic or metal tubing:
You may disassemble and reassemble Swagelok® tube fittings many times, but the assembly process is slightly different than the first assembly.

1. Insert the tube with pre-swaged ferrules into the fitting until the front ferrule seats against the fitting body.
2. Rotate the nut finger tight.
3. While holding the fitting body steady, tighten the nut slightly with a wrench.

E.2 Common Replacement Parts

Tubing
Campbell Scientific can provide several types and sizes of plastic tubing as shown in TABLE E-1. A tubing cutter, pn 7680, can be used to cut these tubes.

TABLE E-1. Available plastic tubing sizes, construction, and usage guidelines

CSI pn	Tubing Type	OD (in)	ID (in)	Length (ft)	Construction	Notes
15702	Synflex 1300	1/4	0.17	500	Black HDPE jacket, overlapped aluminum tape, ethylene copolymer liner	Aluminum layer limits diffusion; best for sample tubes
15703		3/8	1/4	250		
19164		1/2	3/8	250		
26506	LLDPE	3/8	1/4	500	Black linear low-density polyethylene	More flexible than HDPE
25539		1/2	3/8	500		
19499	HDPE	5/8	1/2	100	Black High-density polyethylene	Required for larger diameter

Tubing inserts
Inserts are recommended for use in plastic tubing. These inserts become permanently attached to the tubing at the first assembly, so spare inserts may be needed for replacing the ends of tubing.

FIGURE E-1. Swagelok® insert

TABLE E-2. Dimensions and part numbers for Swagelok® inserts			
Tubing OD (in)	**Tubing ID (in)**	**Swagelok® pn**	**CSI pn**
1/4	1/8	B-405-2	15834
1/4	0.17	B-405-170	15830
1/4	3/16	B-405-3	15713
3/8	1/4	B-605-4	9845
1/2	3/8	B-815-6	17380
5/8	1/2	B-1015-8	19495

Ferrules
Each Swagelok® fitting comes assembled with the front and back ferrules included. These ferrules are permanently swaged onto the tubing at the first assembly, so spare ferrules may be needed for replacing the ends of tubing.

Back ferrule Front ferrule

FIGURE E-2. Front and back Swagelok® ferrules

TABLE E-3. Dimensions and part numbers for Swagelok® ferrules		
Tubing OD (in)	**Swagelok® pn (front/back)**	**CSI pn (1 set)**
1/8	B-203-1/B-204-1	N/A
1/4	B-403-1/B-404-1	15890
3/8	B-603-1/B-604-1	15889
1/2	B-813-1/B-814-1	N/A
5/8	B-1013-1/B-1014-1	N/A

Plugs
Swagelok® plugs are used to plug a fitting when its tube is disconnected. It is strongly recommended to plug all fittings to keep them clean. Spare plugs may be needed if they become lost or damaged.

FIGURE E-3. Swagelok® plug

TABLE E-4. Dimensions and part numbers for Swagelok® plugs		
Tubing OD (in)	**Swagelok® pn**	**CSI pn**
1/8	B-200-P	26803
1/4	B-400-P	15891
3/8	B-600-P	13712
1/2	B-810-P	17381
5/8	B-1010-P	N/A

Caps
Swagelok® caps are used to cap the end of tubes when they are disconnected from the fitting. It is strongly recommended to cap all disconnected tubes to keep them clean. Spare caps may be needed if they become lost or damaged.

FIGURE E-4. Swagelok® cap

TABLE E-5. Dimensions and part numbers for Swagelok® caps		
Tubing OD (in)	**Swagelok® pn**	**CSI pn**
1/8	B-200-C	19219
1/4	B-400-C	15831
3/8	B-600-C	15547
1/2	B-810-C	17335
5/8	B-1010-C	19496

Appendix F. Installing the AC/DC Power Adapter Kit

The AC/DC Power Adapter Kit is configurable within the CPEC200 system enclosure to allow the CPEC200 to be powered from AC mains power. A peripheral mounting kit (pn 16987) is necessary to install the AC/DC adapter into the CPEC200 system enclosure. The mounting kit includes a bracket, a Velcro® strap, and the necessary nuts and screws.

The following steps describe the mounting procedure.

1. Install the peripheral mounting kit inside the CPEC200 system enclosure by threading the Velcro® strap through the bracket.

2. Place the bracket at the backplate of the enclosure below the datalogger and attach it with the screws included in the mounting kit (see FIGURE F-1).

FIGURE F-1. Peripheral mounting kit installed in CPEC200 enclosure

3. Place the power supply on the mounting bracket and secure the power supply's cable to the back of the mounting bracket with a wire tie as shown in FIGURE F-2.

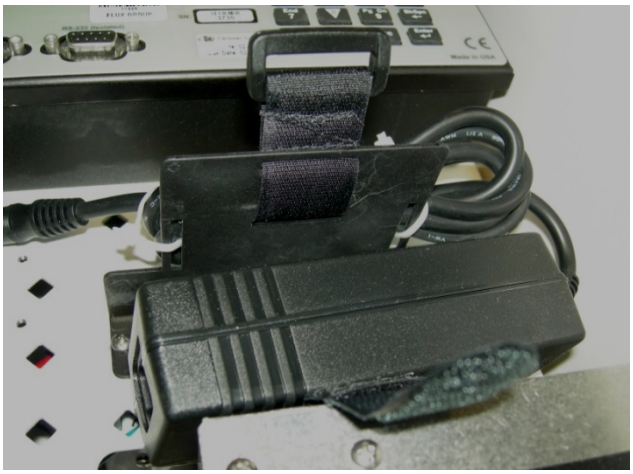

FIGURE F-2. Power supply in mounting bracket

4. Tighten the Velcro® strap to secure the power supply to the mounting bracket (FIGURE F-3).

FIGURE F-3. Secured power supply in mounting bracket

5. Connect the pigtail connector to the DIN rail connectors as shown in (FIGURE F-4).

NOTE The wire with the white strip is +12 V.

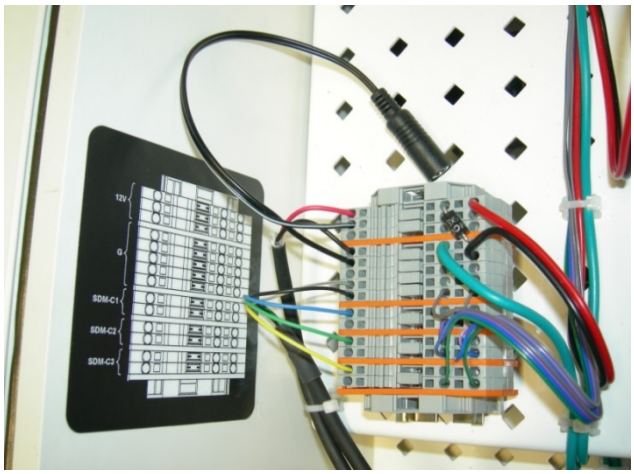

FIGURE F-4. Connections for the power supply in CPEC200 enclosure

6. If the AC/DC adapter kit was ordered with a detachable power cord, remove the enclosure feedthrough cap, insert the end of the power cord, and plug it into the AC/DC adapter.

NOTE If a long AC power cord is required, have a certified electrician connect the field-wireable plug that is supplied with the kit, to a user-supplied cord.

7. Plug in the 12 V connector as configured in FIGURE F-5.

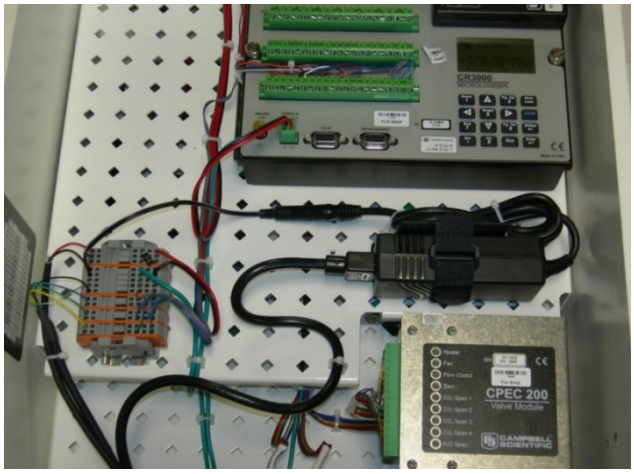

FIGURE F-5. Powered supply in CPEC200 enclosure

Appendix G. CPEC200 Scrub Module Installation, Operation and Maintenance

The CPEC200 Scrub Module provides a stream of air that has been scrubbed of CO_2 and H_2O and is used for zeroing the EC155. The module is housed in a fiberglass enclosure that can generally be mounted to the same structure as the CPEC200 system enclosure. The enclosure is shown in FIGURE G-1, and the specifications can be found in Appendix G.2, *Scrub Module Specifications*.

FIGURE G-1. CPEC200 scrub module

G.1 Theory of Operation

The CPEC200 Scrub Module provides an air stream with CO_2 and H_2O removed to zero the EC155. It includes a small diaphragm pump to push the zero air to the analyzer and three bottles containing a molecular sieve to remove CO_2 and water vapor from ambient air. The pump provides approximately 1.5 LPM flow. It has a heater and fan to keep it within its operating range (5 to 50 °C) over ambient temperatures down to –30 °C. The CPEC200 scrub module is intended to replace the cylinder of compressed zero air. The optional valve module for automated zero is also required if using the scrub module.

The CPEC200 scrub module pump pulls ambient air through three bottles of molecular sieve and pushes it to the valve module. The ambient air inlet and zero air outlet fittings are on the bottom of the enclosure. It uses a small diaphragm pump that is mounted in an insulated, temperature-controlled box inside the weather-tight fiberglass enclosure.

The following are descriptions of the operating parameters of the scrub pump.

Pump Control

The pump is turned on automatically when the **Zero Air** valve is selected. The pump has a maximum flow rate of approximately 2.0 LPM and a maximum pressure rise of approximately 90 kPa.

Scrub Pump Outlet Pressure

The measured outlet pressure of the pump is reported in public variable **scrub_press**. This pressure will normally be 3 to 20 kPa when it is running.

Scrub Pump Temperature

The temperature of the scrub pump is reported in public variable **scrub_tmpr**. The operating range of the pump is 5 to 50 °C. If the scrub pump temperature is outside this range, the CPEC200 will disable the pump. The scrub pump module has a heater (drawing 8W while operating) that turns on if the pump temperature falls below 7 °C. If the CPEC200 is started at cold temperature, it may take up to 20 minutes to warm the scrub pump module (from –30 to 5 °C). When it reaches 7 °C the heater will cycle on/off as needed to maintain this temperature.

The scrub pump module has a fan (drawing 0.7W while operating) that turns on if the pump temperature rises above 45 °C. The fan will stay on until the scrub pump temperature falls below 40 °C.

G.2 Scrub Module Specifications

Operating temperature:	–30 to 50°C
Power consumption[i]	
Quiescent:	0 W
With pump on:	2 W
With heater on:	8 W
With fan on:	0.7 W

G.3 Installation

There are numerous mounting options for the scrub module including tripod (mast or leg), tower, or pole. Enclosure mounts are specified when ordering the CPEC200 Scrub Module and mounting the module is accomplished in the same way as mounting other CPEC200 enclosures as described in Section 5.1, *Mounting*.

Connect the scrub module cable to the CPEC200 system enclosure, receptacle marked **Scrub Module**. Remove the Swagelok® plugs from the inlet and outlet and store them in the mesh pocket in the door. Install the Swagelok® nut with screen on the **Ambient Air** inlet. Connect a 1/4-in OD tube from scrub module to valve module on the **Zero** inlet. Remove the desiccant pack from its plastic bag and place the pack in the mesh pocket.

[i] The typical average power consumption is generally negligible in a CPEC200 system because it is used for a short time each day.

Edit the CPEC200 CRBasic program to set constant **SCRUB_MODULE** = **True** and recompile.

The CPEC200 program will add the appropriate variables. It will control the temperature of the scrub module whenever it controls the temperature of the valve module. It will turn on the scrub module pump whenever the **Zero Air** valve is selected. The scrub module will push a flow of ambient air that has been scrubbed of CO_2 and water through the valve module to the EC155.

G.4 Maintenance

Once per year, refill the first bottle with fresh molecular sieve (CSI pn 27450, molecular sieve 13X, 1.6-2.5 mm beads, 250 g. or VWR pn AAB21109-30) according to the following steps:

1. Power down the CPEC200 or unplug the scrub module cable from the CPEC200. This will ensure the scrub module pump does not turn on while you replace the molecular sieve.
2. Open the door of the scrub module enclosure to expose the bottles containing the molecular sieve as shown in FIGURE G-2.

FIGURE G-2. Scrub module interior

3. Disconnect the fully exposed black tube (S-shaped and tied to the center of the cover as shown in FIGURE G-2) at both ends. This tube remains captive to the cover plate.

NOTE Disconnecting this tube ensures the bottles are not pressurized when the cover is removed. The scrub module has been designed to require this tube to be disconnected before removing the cover as a safety precaution.

4. Loosen the four thumbscrews (shown in FIGURE G-2) and remove the cover plate to gain access to the bottles (FIGURE G-3). Note that the thumb screws are captive; they remain attached to the cover plate.

FIGURE G-3. Interior of CPEC200 scrub module with tubing and cover removed

5. Disconnect the remaining tubes from the bottles at the Swagelok® fittings.

NOTE Caps are spring loaded!

6. Remove the center bottle from the scrub module and set it aside.
7. Remove the left bottle and place it in the center position.
8. Remove the right bottle and place it in the left position.
9. Refill the bottle that was removed by twisting while pulling to remove the top cap. The caps are held in place by friction only and the spring inside the bottle may eject the cap.

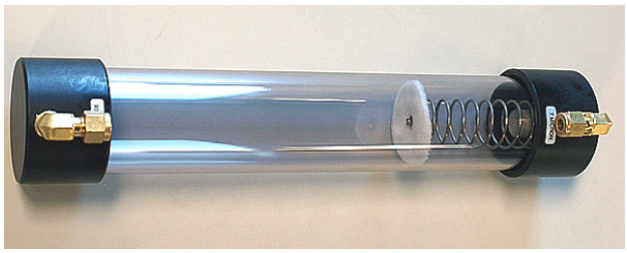

FIGURE G-4. Empty bottle showing the top (on the right with spring) and bottom (left) caps

10. Remove the spent molecular sieve in accordance to local ordinances and the manufacturer's Material Data Safety Sheet.
11. Refill the bottle with new molecular sieve and replace the top cap (the cap with the spring).
12. Replace freshly filled bottle in the open position on the right side of the enclosure.
13. Reconnect the tubes to the bottles.
14. Replace the cover plate and retighten the thumb screws.
15. Reconnect the black tube in its original location over the cover plate.
16. Close the scrub module enclosure.
17. Reconnect the scrub module cable as in G3, *Installation*, and restart the CPEC200.

Appendix H. CPEC200 Pump Replacement

H.1 Introduction

A properly maintained CPEC200 system will exceed the lifetime of the system's pump. This section provides step-by-step instructions for the user to replace the system pump (pn 26402), rather than needing to return the pump enclosure to Campbell Scientific for replacement.

H.2 Removal

To remove a CPEC200 pump, carry out the following steps:

1. Place the pump module on a horizontal surface.

NOTE It is very difficult to replace the pump if the module is mounted vertically on a tower.

2. Remove the four, #10 self-sealing screws that hold the filter assembly within the CPEC200 pump module enclosure (see FIGURE H-1). If these screws become lost or damaged, replace them with pn 26412.

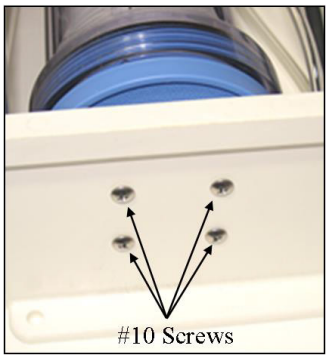

FIGURE H-1. Four screws holding filter assembly inside CPEC200 pump module enclosure

3. Stand the filter up in the enclosure and remove the tubing from the filter inlet by loosening the nut with an 11/16" wrench. Remove the tubing from the outlet of the filter by loosening the nut with a 9/16" wrench (FIGURE H-2).

NOTE The filter cartridge in the pump module is unlikely to clog over the lifetime of the CPEC200 system. If the filter holder or cartridge become damaged, however, the replacement parts are pn 26407 (filter holder) and pn 26408 (filter cartridge).

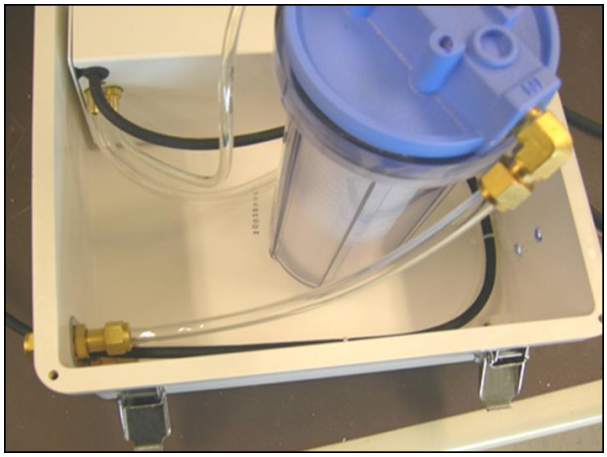

FIGURE H-2. Upright filter unit in enclosure

4. With the filter assembly removed from the CPEC200 pump module enclosure, remove the six #4 screws (FIGURE H-3) from the pump assembly. If these screws become lost or damaged, replace them with pn 488.

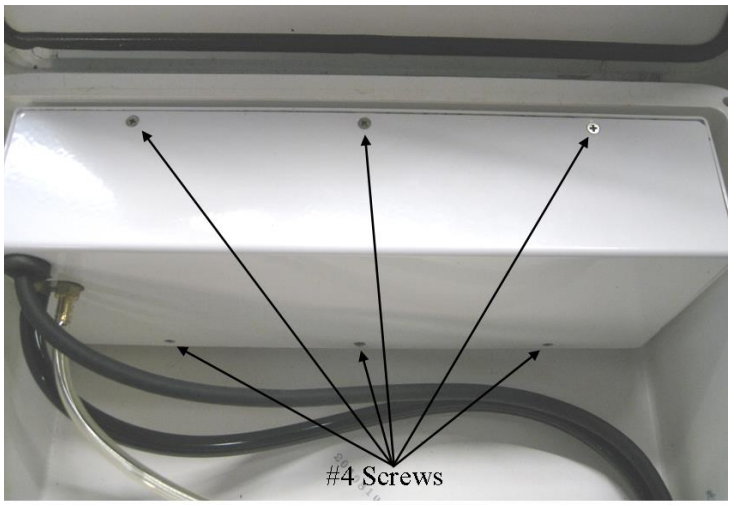

FIGURE H-3. Location of #4 screws of pump assembly

5. Once the screws are removed, fold back the pump assembly from the shell bottom as shown in FIGURE H-4.

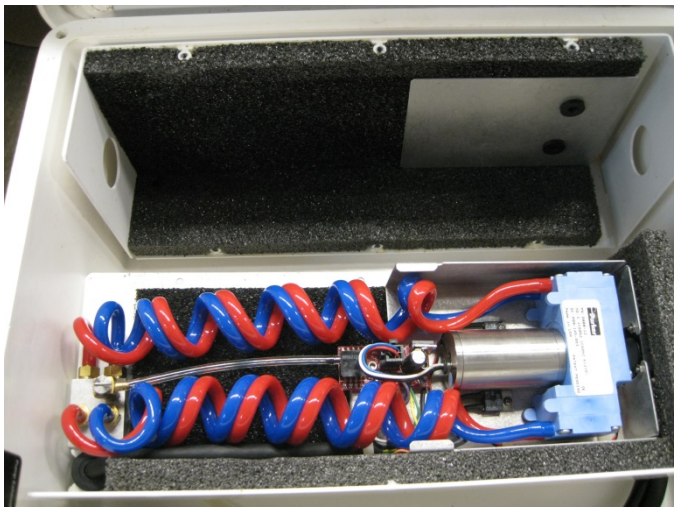

FIGURE H-4. Exposed CPEC200 pump assembly

6. Remove pump connector from the pump electronics (FIGURE H-5).

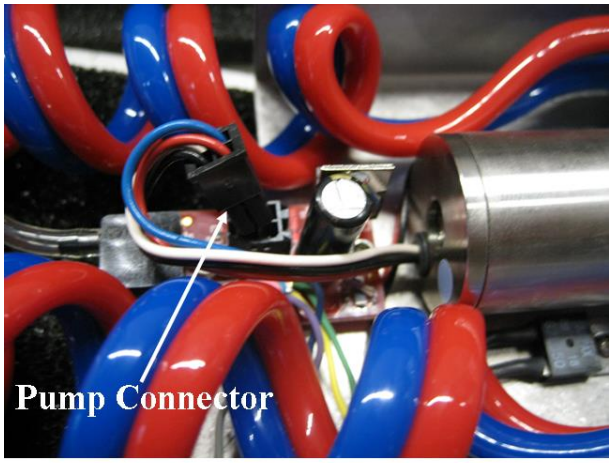

FIGURE H-5. Location of pump connector in CPEC200 pump electronics

7. Gently lift the pump assembly from foam, leaving the tubes attached. Turn it over and remove the two self-tapping #6 screws that attach the pump to the metal box, as shown in FIGURE H-6. If these screws become lost or damaged, replace them with pn 13535.

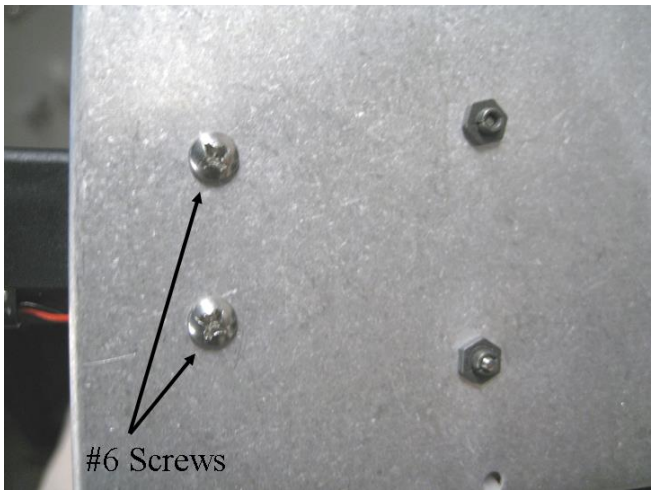

FIGURE H-6. Self-tapping screws attaching pump to metal box

8. Cut the blue (inlet) and red (outlet) tubing on each side of the pump behind the barbed connector as shown in FIGURE H-7.

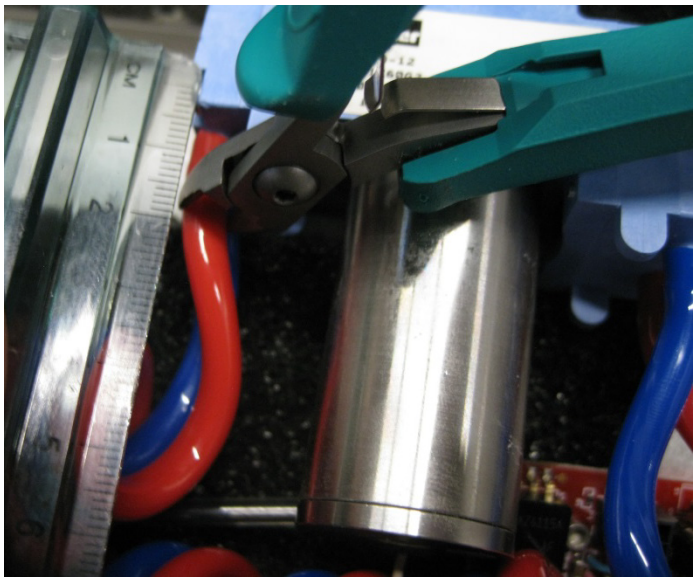

FIGURE H-7. Location of cuts to remove pump assembly from tubing

9. Remove the pump from the assembly.

H.3 Installation

To reinstall a CPEC200 pump, carry out the following steps:

1. Position the pump with the label up and connect the coiled tubing on both sides of the pump (see FIGURE H-8). Blue tubing connects the inlets and red connects the outlets as directional arrows show on the side of the pump (FIGURE H-9).

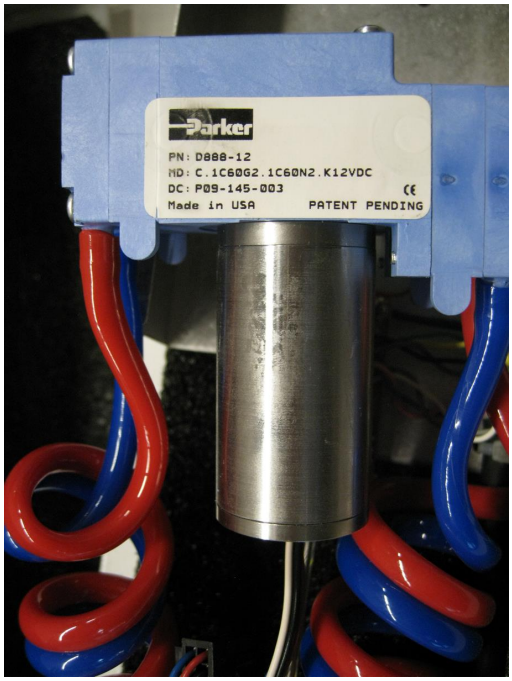

FIGURE H-8. Inlet and outlet tubing reconnected to pump

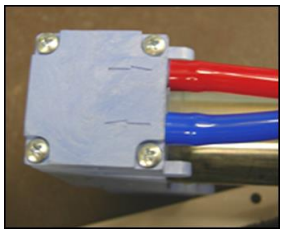

FIGURE H-9. Pump side with inlet and outlet tubing connected

2. Reattach the pump to metal box with two self-tapping #6 screws on the back of the pump module electronics plate (FIGURE H-6).

NOTE Be careful not to pinch the fan wires under the pump and do not overtighten screws.

3. Reattach the pump connector to the pump electronics (FIGURE H-5).

4. Place the pump assembly back into the foam on the shell cover. Make sure the fan is in the hole in the end and the small tab on the metal box is seated in the slit in the foam.

FIGURE H-10. Proper positioning of CPEC200 in shell cover

5. Hold the pump assembly securely to the shell cover while replacing the shell cover to the shell bottom. Make sure the fan does not slide back out of its hole in the foam. Fasten the shell cover in place with the six #4 screws (see FIGURE H-3).

6. Reconnect the tubing to the inlet and outlet of the filter assembly (see step 2 of removal and refer to FIGURE H-3).

NOTE Hold the fitting with a backup wrench to make sure the fitting does not unscrew from the filter holder lid. Be careful to not overtighten the fittings as this could cause damage to the hardware. Finger tighten the fittings first, then snug slightly with a wrench.

7. Rotate the filter holder into position and mount in the enclosure with four #10 screws (FIGURE H-1).

NOTE Do not overtighten screws.

Campbell Scientific Companies

Campbell Scientific, Inc.
815 West 1800 North
Logan, Utah 84321
UNITED STATES
www.campbellsci.com • info@campbellsci.com

Campbell Scientific Africa Pty. Ltd.
PO Box 2450
Somerset West 7129
SOUTH AFRICA
www.csafrica.co.za • cleroux@csafrica.co.za

Campbell Scientific Australia Pty. Ltd.
PO Box 8108
Garbutt Post Shop QLD 4814
AUSTRALIA
www.campbellsci.com.au • info@campbellsci.com.au

Campbell Scientific (Beijing) Co., Ltd.
8B16, Floor 8 Tower B, Hanwei Plaza
7 Guanghua Road
Chaoyang, Beijing 100004
P.R. CHINA
www.campbellsci.com • info@campbellsci.com.cn

Campbell Scientific do Brasil Ltda.
Rua Apinagés, nbr. 2018 ─ Perdizes
CEP: 01258-00 ─ São Paulo ─ SP
BRASIL
www.campbellsci.com.br • vendas@campbellsci.com.br

Campbell Scientific Canada Corp.
14532 – 131 Avenue NW
Edmonton AB T5L 4X4
CANADA
www.campbellsci.ca • dataloggers@campbellsci.ca

Campbell Scientific Centro Caribe S.A.
300 N Cementerio, Edificio Breller
Santo Domingo, Heredia 40305
COSTA RICA
www.campbellsci.cc • info@campbellsci.cc

Campbell Scientific Ltd.
Campbell Park
80 Hathern Road
Shepshed, Loughborough LE12 9GX
UNITED KINGDOM
www.campbellsci.co.uk • sales@campbellsci.co.uk

Campbell Scientific Ltd.
3 Avenue de la Division Leclerc
92160 ANTONY
FRANCE
www.campbellsci.fr • info@campbellsci.fr

Campbell Scientific Ltd.
Fahrenheitstraße 13
28359 Bremen
GERMANY
www.campbellsci.de • info@campbellsci.de

Campbell Scientific Spain, S. L.
Avda. Pompeu Fabra 7-9, local 1
08024 Barcelona
SPAIN
www.campbellsci.es • info@campbellsci.es

Campbell Scientific Southeast Asia Co., Ltd.
877/22 Nirvana@Work, Rama 9 Road
Suan Luang Subdistrict, Suan Luang District
Bangkok 10250
THAILAND
www.campbellsci.asia • info@campbellsci.asia

Please visit www.campbellsci.com to obtain contact information for your local US or international representative.